AGGREGATE PRODUCTIVITY TRENDS AND FORECASTS IN U. S. IRON AND STEEL INDUSTRY

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AGGREGATE PRODUCTIVITY TRENDS AND FORECASTS
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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF ILLUSTRATIONS

SUMMARY

Traditionally most productivity measures in the Iron and Steel Industry have concentrated on the relationship between some measure of output, such as output in constant dollar value, or quantity of physical units produced and a measure of labor input, such as manhours, employment costs, number of employees, etc. Productivity analysis and interpretation by only considering one input factor, such as labor, can be quite misleading since the effects and interdependencies of other input factors are not considered. It is recognized that a better interpretation of productivity trends in industry can be achieved by including the effect of other inputs, such as capital, materials, or energy in addition to labor. It is the purpose of this thesis to develop a "composite productivity" measure for the U. S. Iron and Steel Industry. Composite productivity is defined as the relationship of three outputs, namely, revenues, tons produced and tons shipped in respect to the added effect of four inputs, labor, materials, electric energy and capital.

By using the aggregate industry's historical data and available forecasting and regression techniques, model equations for each individual output and input factor are obtained. The model equations are used to forecast composite productivity trends.

Results show decreases in composite productivity when the sum of the four inputs factors mentioned is considered. When the effect of capital is excluded and composite productivity is measured in respect to the sum of labor, materials, and electric energy, small productivity increases are obtained. This means that the constant dollar capital increases have given a continuing decrease in composite productivity.

Sensitivity analysis of composite productivity in respect to variations in the rate of changes of the individual input factors is considered. This allows assessment of the relative importance of each input factor in effecting composite productivity change.

A capacity expansion hypothesis is considered. Composite productivity is measured from 1977 to 1983, using estimates published in steel industry literature about the capacity expansions and capital expenditures required to be able to supply the expected future steel demand. Results show that if the additions of capacity, replacements and pollution control equipment actually require the expected capital expenditures, then composite productivity will continue to decrease in the future.

CHAPTER I

INTRODUCTION

Background and Description of the Problem

The concept of productivity and issues related to it have been much discussed in recent years. Generally speaking, productivity implies the relationship of some measure of output in respect to a single or several measures of input. Traditionally, most productivity measurements have concentrated on what has been called partial measures of productivity because they relate output to a single input component. The most commonly used input factor is a labor input measure such as manhours, number of employees, employment costs, etc. Productivity analysis and interpretation limited to consideration of only a single input factor can be misleading because the effects and interdependencies of other inputs are not taken into account. For example, an increase in productivity indicated by measuring output in respect to manhours could be due to a more efficient utilization of labor, but it also could be caused by the utilization of better and more expensive materials, more expensive and sophisticated equipment, different technology, larger amounts of skilled laborers, etc. The effects of other input changes are not explicitly considered in any partial productivity measures.

More recently there have been attempts to develop a more complete measure of productivity. These have been labeled total and composite measures of productivity. These relate a measure of output, normally in either, value or physical units, in respect to several tangible inputs factors that contribute to the production of output. The use of a given set of inputs in a particular situation is determined generally in terms of the magnitude of contribution that inputs have on output.

The concept of productivity is clear. In either partial, composite or total measures, productivity is expressed as a ratio between output and the inputs associated with producing it. In essence, the concept of productivity is related to the optimum utilization of scarce resources.

The measurement of productivity is not always as clear cut and is considered by many authors as the most controversial aspect of productivity studies. Most often, approximations, conversions and estimations have to be performed in output and input factors in order to yield the particular productivity measure of interest. Comparison of productivity among different countries, industries, and firms are not always valid, either because the measurement procedures themselves are not comparable or because that the characteristics of output and input factors are not similar.

Quality improvements in the output and input factors utilized are seldom quantified, especially in the productivity measures expressed in terms of physical quantities.

There is no agreement and no standard approach for dealing with other measurement issues such as: the choice of a weighting system for measuring heterogeneous outputs, how to deal with intangible capital expenses, and the returns associated from them, the treatment of tangible capital flow, the non-homogeneous nature of the labor input, etc.

The importance of seeing productivity improvements at the firm level is the result of recognizing the capital effects that firm productivity can have upon the industry level and the overall National Economy. There is concensus that productivity has a most important bearing on costs, prices and profits, on competitiveness in domestic and foreign markets, business success, and growth, on inflation and the prospect of offsetting the continuing increases in operating costs. Unfortunately, no concensus yet exists about what can be done about measuring productivity at the individual enterprise or firm level.

When there is a large gap between changes in productivity (output/manhour) and labor compensation (compensation/manhour) the result is a large increase in unit labor costs. This has inflationary effects because prices and wages rise at different rates setting in motion an inflationary spiral. This behavior can be stopped by "increasing the rate at which productivity grows, so that wages can rise without increasing unit labor costs so the pressures on prices are reduced".[1] This effect upon inflation, is so important that productivity improvement is considered an extremely important aspect in the improvement of the standard of living of a nation and of society.

Steel industry productivity has been commonly measured and analyzed by considering only one input factor of production, the labor input, expressed in terms of manhours. The U. S. Bureau of Labor Statistics, B.L.S., has been publishing indexes of output per manhour for major industry classifications in the U. S., which covers data since 1939.[2] Relying solely on these output per manhour measures for analysis and interpretation of productivity trends, can be quite dangerous in a highly capital intensive industry such as steel. The failure to explicitly consider capital invested in machinery and raw materials in the productivity measure can certainly lead to erroneous interpretations. The ratio of output per manhour excludes the capital and materials inputs. This implies that the productive efficiency of these two factors can only be evaluated indirectly in terms of their effect on manhour output.

For example, a new piece of machinery or a new technological process can double output per manhour, but its cost and installation expressed in constant dollars can twice exceed the cost of new units of the previous equipment or process. In this case, output per manhour would increase, but clearly capital productivity would decrease and depending upon the relative importance of labor and capital the net effect could be a productivity decrease. This same new machinery or process will use different raw materials or different amounts of the same materials, will use energy at different rates, will require new maintenance expenses, etc. All these additional input factors of production are not considered in a partial measure such as output per manhour. Despite these deficiencies the Bureau of Labor Statistics output per manhour indexes can provide some insight into how the steel industry compares in this measure with other industries and with the overall economy. The importance given recently to the productivity in steel might be a result of the rather pronounced lag in its productivity growth compared to the growths in productivity of the total private economy and by manufacturing industries in general. Hogan[3] mentions that the B.L.S. figures show a yearly growth rate in output per manhour of 1.7 percent from 1947 to 1970 in the steel industry compared with a 2.9 percent rate for all manufacturing industries and 3.2 percent rate for the total private economy. During the decade of the fifties, it averaged approximately 1 percent annual growth rate. This increased to 4.3 percent annually in the first half of the sixties keeping in pace with the all manufacturing rates. But this rate decreased sharply from 1965 to 1970, averaging 0.4 percent annually well below the also decreased 2.0 percent annual growth for the total private economy.

The large productivity (output per manhour) advantage that the U. S. had on steel in the early sixties has almost disappeared. This behavior is shown in the following table.

Table 1.1. Manhours Per Ton of Shipped Steel[4]

Country	1960	1965	1970
Japan	44.2	27.9	12.4
West Germany	24.2	21.6	14.5
U. S. A.	15.0	12.2	11.9

The younger steel industries of West Germany and especially Japan have been able to accomplish much greater productivity gains than the more mature U. S. steel industry. These results are not alarming, it is easier for an emerging industry to install more productive machinery and processes than in an already established industry. In the older industries the matching of old and new processes and equipment is not always possible or desirable and often investment in more productive equipment is postponed for some time in the hope of more compatible technological or economic alternatives in the future. This means that younger steel industries of other countries are in a better position than the U. S.'s to obtain productivity gains. The small advantage still maintained by the U. S. can be lost if the steel industry does not find the way to almost immediately replace obsolete facilities with newer and more efficient plants, equipment, and processes. A major problem is that the necessary capital to make these replacements has been difficult to acquire in recent periods of great inflationary pressures and low profit margins generated by the industry.

Objectives of the Study

The overall objective of the study is to provide a composite productivity measure to be used in measuring productivity trends for the aggregate U. S. Iron and Steel Industry. A composite productivity measure is defined as the relationship between annual level of output factors such as shipments, production and revenues in respect to the sum of the annual level of important input factors such as labor, materials, electric energy and capital. Productivity measurement in the iron and steel industry has been limited to the analysis of partial productivity measures, normally by measuring output in respect to manhours of labor input. Total or composite productivity measures, that explicitly take into account the effect of various input factors, have not been found in the literature. It is the purpose of this work to measure the trends in composite productivity in order to observe how they compare with the traditional productivity measures that only consider the labor input. This will provide additional information about the effects of other inputs factor in relation to the steel industry's productivity.

The objectives of the study can be summarized in the following points:

1. To define the composite productivity measures by using shipments, production, and revenues as output factors,

the first two in terms of tons and revenues in terms of constant dollar value. Input factors are labor materials, electric energy and capital, also in terms of constant dollar value. Ratios of each output factor in respect to the sum of the four inputs are used as composite productivity measures. These are:

Shipments (tons)/[labor + materials + electric energy + capital] (constant dollars)

Production (tons)/[labor + materials + electric energy + capital] (constant dollars)

Revenues (constant dollars)/[labor + materials + electric energy + capital](constant dollars)

The ratio of each output factor in respect to the sum of labor, materials, and electric energy, excluding capital is also considered. This is done because the first three input factors are variable costs, dependent on the level of output, whereas capital, measured as value of capital stock, is a fixed cost which does not vary with the level of output, at least in the short run. This difference in the nature of the input factors suggests that a productivity measure that does not combine them, should also be considered.

2. To obtain from analysis of historical data, valid model equations for each output and input factor, using available forecasting and regression techniques. The model equations will serve the purpose of a forecasting or prediction package from which one period

ahead forecasts, or forecasts for longer periods of output and input factors can be obtained.

3. To use the model equations to compute annual productivities. Productivity measurements using one period ahead forecasts will be compared to productivities obtained by using the actual data from 1950 to 1976. The models will be used to provide productivity forecasts from 1977 to 1986. The productivity trends for both the actual and forecasted data will be compared in terms of average rates of change.
4. To obtain a better understanding of the effects of individual input factors rate of change on productivity trends. Each input factor forecasted rate of change will be increased and decreased by the same amount in order to observe what effects the changes have on the productivity trends.
5. To be able to use the model equations together with assumptions about capacity expansion programs that the steel industry has for the future, in order to reach some conclusions about what effects these programs might have on the industry's composite productivity.

A composite productivity measure of the aggregate U. S. steel industry can be used as an industry benchmark to which individual firms can compare their individual composite productivity performance. Obviously, this would require adjustments because in most cases no individual firms might be representative of the aggregate industry's operations.

The use of the model equations package can be summarized as follows:

1. To forecast next year's level of input and output factor from which composite productivity can be compared.
2. To forecast for longer lead times in order to obtain an estimate of long term productivity trends.
3. To serve as a management tool, not only for productivity calculations, but also in the area of planning, concerning costs, substitution of inputs, justification of wage and salary increases, capital expenditure decisions, and in general, where the impact of inputs on outputs is of importance.

The selection of shipments, production and revenues as output factors do not require much justification since they are the most commonly used output measures in the steel industry.

Production data measures the net ton amount of raw steel produced and gives an indication of the overall industry production policy in terms of expectations about future demands, production capabilities and current inventory levels. This is the most important output factor for measuring the efficiency of conversion of the inputs. Shipments measures the finished steel tonnage shipped from the steel mills to the customers and gives an indication of current levels of demand.

Revenues represent the value of shipments, dependent on current demand and level of prices of finished steel products. Revenues and inputs factors will be adjusted in constant value terms in order to be used in productivity calculations. This point will be expanded in later sections.

CHAPTER II

LITERATURE SURVEY

This chapter will cover some of the most important productivity issues treated in the relevant literature about this topic. The first part of the chapter will deal with issues of productivity in general, pertaining to the economy, industry and firm level. This first part will be divided into three sections: Productivity Meaning and Implications; Treatment of Outputs and Inputs; Measurement Problems. The second part of the chapter will cover productivity related to issues of the U. S. iron and steel industry.

Productivity Concepts

A great deal has been written about productivity, but unfortunately a large proportion of that writing has been stated in rather vague and general terms. This vagueness in productivity literature might be the result of authors failing to realize that any productivity measure, topic or discussion should always be stated in terms of the purpose it is going to serve and the particular system that it is going to measure. There is no such thing as a "best measure of productivity." The success of any productivity measure can only be gauged in terms of how useful it is to management and how realistically it measures the particular output-input relationship that management is interested in.

Solomon Fabricant agrees that despite the importance and attention given to productivity the subject is surrounded with confusion. He mentions:

> First, people employ the same term but mean different things. As a consequence, various figures on productivity change come into use, and these often differ in significant degree. Further, the rate of productivity change is not a fixed quantity... What the past or current rate of productivity change is, depends on the particular period for which the calculation is made. If no reference is made to the period, and if the period varies considerably from one context to another, confusion results. In addition, the statistical information available for calculating productivity indexes is deficient in various respects... Failure to specify the methods and the assumptions involved in the process of estimation, or failure to understand them, adds to the confusion.[5]

<u>Productivity Meaning and Implications</u>

There is good concensus among authors about what is meant by productivity. A measure of productivity is usually defined as an output-input ratio, which relates the output (goods and services) to one or more of the inputs which were associated to that output. Productivity is interpreted as the efficiency of conversion of the inputs to produce a given output.

As mentioned in the previous chapter, productivity measures are normally classified in partial and total productivity measures.

Partial productivity refers to the relationship of total output to a single input factor, normally labor or capital. Total productivity attempts to relate total output to all inputs factors used to provide the output. There is not complete agreement yet about what constitutes "all inputs." When we are dealing with National or Economy Productivity "all inputs" are normally all tangible inputs such as labor, capital and land. For the firm level, Craig and Harris[6] explain that more inputs are necessary to correctly express total productivity. Input factors such as raw materials, energy, purchased parts, miscellaneous goods and services are not included in a total productivity National Economy measure because they represent intermediate products or goods and must not be included in order to avoid double counting of output. These additional inputs factors must be included in the typical firm total productivity measure.

At the national economy level the most commonly used productivity measure is real output per hour of work, a partial measure. Stein[7] argues that if labor compensation per hour increase at the same rate as output per hour, unit labor costs will remain stable, and that if the shares of compensation in the economy remain unchanged then on the average, prices should remain stable. He further mentions that the price level generally moves closely with the ratio of compensation per hour to output per hour except for cyclical or other short interruptions. According to this behavior, wage increases equal to the average increases in labor productivity expressed in terms of output per manhours should not have inflationary effects. The mechanism of the Clark-Hanson Law referred to by Craig and Harris[8] is that prices would be increased in those sectors with lower than average productivity and reduced in sectors where productivity is above average, the net effect being an all around increase in wage rates, and general price level remaining constant. They offer two objections for this behavior to occur in practice. First, that prices are relatively stable or immobile downward. This means that no price reduction will result and that the effect of a wage increase equal to the average productivity gains will be an increase in prices or a reduction of profits. The general price increase will result in further wage increases setting in motion the inflationary spiral. Second, they argue that labor productivity alone is an invalid measure to determine wage increases. Labor productivity can be increased, but the costs incurred to provide this increase must be considered. Relying on labor productivity alone to provide wage increases can result in erroneous decisions, this being one of the dangers surrounding partial productivity measures.

Generally it is assumed that increasing productivity is related to economic growth. However, there is not complete agreement among productivity economists about how much have productivity increases contributed to economic growth. Craig and Harris[9] mention that "correlation of economic growth to total productivity has not been rigorously demonstrated," and that most often partial productivity measures have been used to compare economic growth. Also, analysis of increases in output may show that these are brought about by investment costs that offset most of the output increases.

The point of productivity and changes in economic structure is discussed by Craig and Harris[10] and quantified by Kendrick.[11] These authors point out that there have been economic structural changes in both inputs and outputs that might account for declines in the rate of productivity gains. The first two authors offer four points that could help explain this behavior: 1) Productivity gains from the agricultural sector now contribute less than what they once did because agriculture is becoming a decreasing portion of the economy; 2) the service sector is becoming a larger portion of the economy and consequently its lower than average productivity gains are now having a larger effect than what it once did; 3) the close relationship of year to year changes in productivity indexes and business cycles. Craig and Harris mention that businesses are reluctant to lay off people at the beginning of a downturn resulting in an "excess" labor input. Fortune Magazine[12] explains that there are delays by employees in adjusting to changing needs. Whenever there is a boom, it takes time to find and hire the necessary people. In recessions, employers are reluctant to lay off workers at once, thinking that they might have to rehire them soon. After workers are laid off, and even with the recession on, there is for a while, a typical productivity gain rising faster than output. 4) The Government sector has been growing as an economic factor. Government's output is measured at cost, meaning that its total productivity is always constant and equal to one. As Government becomes an increasing sector of the economy, its inclusion in a productivity measure will tend to reduce the magnitude of productivity gains.

Kendrick's studies mentioned above, quantify the changing structures of inputs and outputs. Concerning data from 1889 to 1957 he states:

> Changes in inputs on a per capita basis have a somewhat different relative importance than straight changes. Thus, capital input increased at an average rate of 2.7 percent a year, about 60 percent more than the 1.7 percent rate of increase in labor input. However, the 1.2 percent rise in capital per head is four times the 0.3 percent rise in labor input per head.[13]

For the company or firm level, Kendrick and Creamer[14] discuss that management has been slow in adopting and relying on productivity studies. This is in part the result of unfamiliarity and inexperience with the productivity concept and the different measurement procedures. It's commonly believed that all the information that productivity studies will give is already contained in their accounting statements. The root of this problem, in the opinion of other authors such as Salter,[15] lies in the fact that there is no theoretical framework on productivity theory in which to base and organize the factual knowledge on productivity. Similar beliefs are expressed by Hines.

> A common difficulty in traditional as well as in modern research is the absence of an operational definition of productivity which is quantifiable. Although most individuals have some notion about productivity, the lack of precision in definition makes validation of clauses for particular approaches to productivity improvement

a difficult task.[16]

Kendrick and Creamer[17] add that one of the most important manifestations of business success is the rate of technological progress and its influence on real costs reduction. In a competitive economy different companies supplying similar workers are exposed to the same price changes. The magnitude of their relative profit margins and competitive advantage has much to do with how successful they are in reducing real costs per unit of input.

Treatment of Outputs and Inputs

National Economy Levels. Most of the work done about productivity at the National Economy level has been in terms of partial productivity. The most commonly used measure relates the total output of goods and services of the private economy, that is the private gross national product, to the total of manhours associated with the production of that output.

One of the most comprehensive studies of productivity, of all levels, has been the work by Kendrick, entitled Productivity Trends in the U.S.[18] It is appropriate to discuss briefly his approach of measuring productivity at the national economy level in terms of labor, capital and land input factors.

Output: The different physical units of output have to be expressed in constant or real dollar value in order to allow for comparisons. This is accomplished by selecting a representative base year and multiplying each output in physical units by its average price in the base year. Several output measures are used. As mentioned before the most commonly used is the Gross Private National Product, which excludes the government output. This measure has the advantage that avoids the downward bias that will be incurred if the government sector is included, due to the treatment of government output at cost. Another used measure is the Net National Product that takes into account additions to capital stock minus estimated depreciation. It differs from Gross National Product that considers only additions to capital stock.

Inputs:

Labor: Manhours worked or manhours paid can be used as labor physical units. Manhours paid would include the added effect of fringe benefits such as vacation pay, holidays, etc. The manhours figure for each industry is multiplied times the base year average wage rate corresponding to each industry.

Capital: Estimation of the capital input is done by using the approach of weighting each years actual value of real stock of capital by the base year's rate of return. This is accomplished by the following computations. 1) The same base year chosen for the output is used. 2) Net additions to capital stock are converted to base year constant dollars. 3) The total actual value of real capital stock is now multiplied by the base year's rate of return. This results is a constant dollar value return for capital. Obviously, this process assumes constant base year efficiency in the use of the stock of capital. The depreciation method is in terms of straight line.

Land: This input is estimated by using other authors estimates of outlays in plant and equipment by major types. The land input is estimated by using the base year ratio of land value to structures value times the constant dollar value of each year's "stock" of structures.

There are cases when no physical unit data are available or estimates are not reliable. In situations like this, a commonly used procedure is to deflate the current dollar value of the input by an appropriate deflator in order to yield the constant dollar input.

Most authors are in agreement that it is difficult to correctly measure capital input. This is in part due to lack of data to correctly assess for the contribution of capital in providing the output, and also to different interpretations given to the flow of capital. Capital input generally refers to the constant dollar value of plant and equipment available for production. Sometimes it includes other assets such as inventories, working capital, and land. However, the two most widespread ways of treating capital are by net stock estimates, similar to Kendrick's approach, and gross stock estimates. Net stock estimates are computed by substracting depreciation by any appropriate depreciation method, and expressing the net stock of capital in constant dollars. The gross stock estimates are derived by keeping assets at their full value until they are scrapped with the gross stock of capital expressed in constant dollars.

Industry Level. Most of the input measurements procedures outlined for the National Economy are applicable also at the industry level. In fact the National Economy measures are constructed by adding individual industry measures.

Industry measures are generally constructed by using physical units and manhours per unit data. The use of "weights" in terms of unit labor cost and unit price are also used when no manhours data is available or reliable. In some instances when no physical unit data is available a common procedure is to deflate the current value of output by an appropriate price index for that output, in order to express it in constant or real value terms.

The Bureau of Labor Statistics (B.L.S.) publishes data on output per manhour for more than forty manufacturing and non-manufacturing industries.[19]

Hines[20] has outlined the measurement procedures most commonly used by the B.L.S.

For industries producing various outputs the terms current period (I_{u_c}) and base period (I_{u_b}) composites are defined as follows:

$$I_{u_c} = \frac{\sum_j q_{i_j} \cdot l_{i_j}}{\sum_j q_{i_j} \cdot l_{o_j}} \quad \text{and} \quad I_{u_b} = \frac{\sum_j q_{o_j} \cdot l_{i_j}}{\sum_j q_{o_j} \cdot l_{o_j}}$$

where q_{o_j} = base period quantity of product j.

q_{i_j} = current period quantity of product j.

l_{o_j} = base period unit labor hours for product j.

l_{i_j} = current period unit labor hours for product j.

The base period composite and current period composite can also be expressed as the ratio of a manhours index to an output index. For the current period composite:

$$I_{u_c} = \frac{\text{manhours index}}{\text{output index}} = \frac{\sum_j q_{i_j} \, l_{i_j} / \sum_j q_{o_j} \cdot l_{o_j}}{\sum_j q_{i_j} \, l_{o_j} / \sum_j q_{o_j} \cdot l_{o_j}}$$

As mentioned earlier most of the manhour data used are based on the concept of hours paid. At the company and even at industry level, it would also be appropriate to compute manhours worked. This would give a better measure of the efficiency of the labor contribution.

Firm and Company Level. At the firm level there is the need to consider additional input factors that contribute to the output, such as raw materials, energy requirements, purchased parts, services, and other miscellaneous inputs. At the National Economy level these factors are already taken into account in the output and input measures and for this reason do not need to be covered again.

The treatment of outputs described at the industry level in terms of either weighted physical units or deflated output value and also used at the firm level. Labor input, again can be estimated either from manhour data or by payrolls deflated by an appropriate composite index of average hourly earnings. Inputs of materials and services are also measured by either counts of physical quantities of materials consumed times a base period price or by taking dollar costs incurred and deflating there by appropriate price indexes. Capital input measurement is always controversial. There are basically two concepts. The capital stock measure and the flow measure. Capital stock measure was described earlier as being either gross capital stock or net capital stock. The concept of capital flow would solve some of the deficiencies of the capital stock concept. What is needed is a measure that would assess the effective capital contribution to the output. Capital contribution should be related to levels of utilization of capacity, the loss of efficiency in older equipment, the different intensity of use of capital capacity depending if there is business expansion or recessions. Data for appropriate capital flow measures are not available in most cases. Authors have used depreciation as a flow measure. This can be regarded as an approximation because depreciation methods vary and often depend on tax regulations. Depreciation is based on accounting principles and not on actual contribution of capital for production of output.

The literature shows several good examples of firm level productivity measurement. J. W. Kendrick and D. Creamer[21] present six case studies drawn from existing corporations. Two are examples of partial productivity that measure output per unit of labor input and four measure total productivity by relating output to the changing relation of labor, materials and services and capital. These examples of different types of productivity measurements stress the point that:

> There is no single measurement formula for the guidance of companies in this estimating process. While the underlying concept of productivity can be uniquely defined, its measurement must be fashioned to serve particular functions and to reflect individual circumstances.[22]

In these cases capital is treated in different ways. In one of the examples the principle of converting machinery and equipment input into "equivalent manpower" is used. This provides with additive units for both labor and capital, because capital input is expressed in equivalent manhours. Two other examples treat capital by computing real term book values and applying a base year rate of return to obtain the capital input. The last case measures the capital input by computing an average annual net investment based on a thirteen period month-end data, expressed in constant dollars.

In their Master Thesis, C. Craig and R. C. Harris[23] provide a chapter dealing with productivity measurement at the firm level. They develop the following total productivity measure:

$$P_T = \frac{O_T}{L + C + R+Q}$$

where P_T = total productivity

L = labor input factor

C = capital input factor (includes land)

R = raw materials and purchased parts input factor

Q = other miscellaneous goods and services input factor

O_T = total output

Total output is computed as the summation of all units produced, times their selling price. Units produced are used instead of units sold in order to more correctly measure the efficiency of conversion. A slight variation in measuring total output in this work is that it includes revenues received from other sources other than production such as interests from bonds and dividends from securities. The authors argue that a portion of inputs are used to provide those revenues and that omiting them would underestimate total output.

Capital is treated by following the concept of service value of capital. This is accomplished by using the lease value of capital in terms of annuities. The amount an annuity depends on the assets original purchase price, which is known, and on estimates of the assets productive life and the average required rate of return to the investors. The rate of return is calculated as a weighted cost of capital in the base year.

> The capital input factor is defined as the sum of annuity values calculated for each asset on the basis of its base year cost, productive life, and the firm's cost of capital.[24]

Other inputs are treated in fairly standard manner.

Physical unit quantities are multiplied by base year wage scales, cost of materials and miscellaneous input costs.

B. W. Taylor and K. R. Davis[25] presented recently an article showing a "Total Factor Productivity" (TFP) measures that disaggregates both outputs and inputs into several components. (TFP) is defined as

$$\mathrm{TFP} = \frac{\overbrace{(S + C + MP) - E}^{\text{Total Output}}}{\underbrace{(W + B)}_{\text{Labor Input}} + \underbrace{[(Kw + Kf) \cdot Fb \cdot df]}_{\text{Adjusted Investor Input}}}$$

where S = sales

C = inventory change

MP = manufacturing plant

E = exclusions

W = wages and salaries

B = benefits

Kw = working capital

Kf = fixed capital

Fb = investors contribution adjustment

df = price deflator factor

This model does not include raw materials as an input factor. The authors argue that many firms view the purchasing of raw materials as the result of the labor of others, meaning that raw materials reflect the efficiency of an external operation and not the specific firm's technology progress.

Materials are not included as input factors and are subtracted from output in the "exclusion" term along with other factors which do not represent results of production, such as supplies, depreciation and rentals. "Manufacturing plant" includes items which are provided internally and are not directly related to the output. These items are separately considered as part of the output because they result from a labor effort which is explicitly being considered in the denominator as a labor input. Such items are maintenance and repairs, machinery and equipment produced internally, research and development. The output term developed this way is a value added output. The capital input is considered in the term "adjusted investors input." As is often done, fixed and working capital in net real dollar value terms are weighted by a base year rate of return to yield the capital input. The labor input is computed from the total yearly labor compensation and adjusted to base year dollars by applying an appropriate deflator.

The National Center for Productivity and Quality of Working Life is an independent federal agency created for the purpose of stimulating productivity growth. The agency has published literature dealing with productivity improvement concepts and has shown examples of these programs at the company level. In one of this agency's more recent publications Jerome A. Mark of the B.L.S. stresses the importance of a firm's comparing their own productivity index to those published by the B.L.S. for different industries, by saying:

> They (indexes) can serve as a benchmark for companies to guage their productivity change in relation to their own industry... Such comparisons could trigger an analysis of why company productivity differed from the industry as a whole, and what can be done about it.[26]

Several other papers are presented in this publication concerning productivity measurement programs in the Aluminum Corporation (ALCOA), warehousing of groceries and a Canadian program for making interfirm productivity comparisons.

Measurement Problems

The measurement of productivity is plagued with definitional and statistical problems. Mark[27] separates them as two fundamental problems. First, due to the difficulties in obtaining direct quantity measures which forces the analyst to use substitute data and other approximations. Second, in most cases, data used for other purposes is the one used for productivity measurements. The concepts and reporting procedures underlying these data might be appropriate for those other uses, such as cost accounting, but not always for productivity measurement.

Kendrick and Creamer mention that the measurement problems

> Include 1) Measuring outputs whose characteristics may change over time. 2) Defining and measuring real capital stocks and 'inputs,' as well as labor inputs when the characteristics of both factors are diverse and changing. 3) Problems of aggregating heterogeneous units of output and input.[28]

The most common measurement problems in treating outputs and inputs are now briefly discussed.

Output

At the national economy level two of the most often addressed problems are the measurement of Government and service sectors. Government's output has been traditionally measured at cost due to the absence of market valuation of the services rendered by the Government agencies. As mentioned earlier, this means that Government's sector productivity is constant over time equal to one.[29] The correct measurement of services is complicated because it is often difficult to obtain the direct quantifiable unit of service that should be used. This means that substitutions have to be made. Normally the value of services are deflated by certain price indexes, but again, not all of the indexes utilized are reliable and appropriate deflators for a given service.

At the industry and firm level most of the complications in output measurement deal with the way of treating quality changes, the introduction of new goods and services or the changing characteristics of existing ones and on the way of aggregating and weighting non-standard units of production.

Quality changes are not often explicitly considered in productivity measurements. It may require cumbersome adjustments that would normally mean keeping track of "pure" price increases and increases in price due to additional costs. The adjustments will increase the output quantity produced to reflect that there has been an increase in quality due to an increased input effort. This means that both output and input consider the quality change and consequently offset each other.

New products is the term given to products which are introduced after the base period. This means that their price has to be tracked back to the base period. It is mentioned[30] that an usual way of doing this is to extrapolate back using the price movement of a closely related product.

Items such as variable purchased goods, interplant transfers, and intermediate inputs require special attention.[31] These factors of production must be kept separately from the main or final output of the company in order to permit to be weighted by either their unit cost or their assigned cost for interplant transfer. In the case of purchased goods and interplant transfers their value should then be subtracted from the main output. In the case of intermediate inputs, their real value may be either added as a cost (input) or deducted from output in order to yield a net or value added measure of output. These procedures attempt to avoid overestimating or underestimating either output or input measures, by insisting in outputs and their associated inputs.

There is not complete agreement on the inclusion or exclusion of other revenues other than production, such as investments, dividends from securities, interest from bonds, etc. The argument can be made to favor either way. What has to be kept in mind is that both output and input expressions should be modified accordingly to include or delete these items.

Another subtle point is the measurement of intangible capital outlays such as advertising, public relations, educational and training programs, research and development. It has been always difficult to quantify the output of activities such as these. If the value of the items are large they should be considered. Common approaches are either to include their real cost in both output and input expressions or to delete them on both. The problem with including them is that there is no immediate change in output derived from these inputs. If they are deleted, the productivity expression will be less comprehensive.[32]

Inputs

Labor. With regard to the labor input the most commonly addressed problems are related to the changing composition of labor, the use of hour worked or hours paid as units of input and the selection of an appropriate weighting factors or deflators indexes to yield values adjusted to base period.[33]

The measurement of the labor input should take into consideration the uneven and changing distributions of the work effort among industries and firms. Manhours is the basic physical unit used in measuring the labor input, but manhours are extremely diverse and their mix changes over time. This means that for correct measurement, unweighted measures relying only on manhours as units of labor should be avoided because they do not take into account this diverse nature of the labor input. Labor should be classified according to skills and/or average compensation rates and the manhours of each classification weighted by the corresponding average hourly labor compensation. Productivity measures that take into account only the production workers as the labor input do not reflect the substitution of one type of labor for another. In most industries there has been an increase in the proportion of nonproduction workers meaning that output per manhour of production workers, alone, is biased upwards. To correctly measure this shift the labor input must include total labor input with manhours of workers, employees, and owners.[34]

Most labor measurement for productivity purposes use manhours paid and not manhours worked. This is done mainly due to lack of data on hours worked. Strictly speaking in terms of productivity the manhour worked viewpoint is more appropriate. The hours paid concept is fictitious from a technological efficiency point of view because it includes additional hours of labor in the production of output that do not contribute to the output at all.

Capital. There is agreement among authors dealing with productivity that capital input is certainly difficult to measure. There is no concensus about conceptual and statistical aspects of capital as an input for productivity analysis. Most of these problems have been discussed in earlier sections of this study, for this reason the following is a brief summary of this important point.

Conceptually, two are the more popular viewpoints:

1. Capital stock measures either gross or net.
2. Capital flow measures.

The measurement of capital stocks requires the cumbersome task of converting every asset's net or gross value to base year dollar terms. At a given period of time the real capital values corresponding to each asset or groups of assets would be a fraction of its original acquisition price, these amounts will be determined depending on the length of time between the time of acquisition and the base and current periods, and on the length of life assumed for each asset.[35]

The measures that use the concept of rate of return as the factor that weights the real capital stock,require the computation of the relation of net income to the total of working and fixed capital, in order to obtain the capital input or investors' input. The net income figure needs to be adjusted not to reflect inventory gains or losses that result entirely from price changes. (Difference between book value and current values of inventories.) The depreciation amounts in book values needs also to be expressed in base period prices.[36]

The second conceptual approach to capital input is that of capital flow. This type of approach attempts to take into account the varying levels of intensity of use of the capital stock over time. The main problem here is lack of data that would allow this measurement. A capital flow measure would require "an aggregate of the capital hours used weighted by the rental value of each type of structure and piece of equipment."[37]

Calculating capital input following similar approaches to that of Craig and Harris, described earlier, requires the computation of annuities and perpetuities to obtain the capital input from fixed and working capital respectively. This calculations can be rather lengthy and involve several other estimations such as productive life of each asset and a weighted average cost of capital for the firm.

Productivity in Iron and Steel Industry

The literature on the iron and steel industry shows very few publications or articles dealing with the topic of productivity. Most of the material found,deals with keeping track of the B.L.S. average annual changed in output per manhour and making comparisons among other industries in manufacturing sector. There have been some Government sponsored studies where good cost data for domestic and international comparisons has been gathered, but it has never been used in the context of productivity measurement. Very little has been done in order to improve or to compare other productivity measures with those published by the B.L.S.

The more important productivity contributions in the iron and steel industry are discussed hereafter.

The Bureau of Labor Statistics publishes every year a bulletin of "Productivity Indexes for Selected Industries." These indexes are partial productivity measures relating output to labor input. Indexes of output, employee hours, number of employees and output per employee hours are computed for the major industry classifications over the last thirty years.

In its 1977 bulletin of productivities,[38] the B.L.S. shows that the steel industry index of output per employee-hour has been increasing at an average annual rate of 1.7 percent from 1950 to 1976 and at a rate of 1.3 percent per year from 1971 to 1976. During the 1971-1976 period the average annual rate of change in output per employee hour in the overall manufacturing sector ranged from a high of 11.1 percent per year gain to a low of -2.46 percent per year decline with an average gain of 2.34 percent per year, considerably higher than 1.7 percent gain in steel. Over the longer period 1950-1976, it ranged from a high of 6.7 percent per year to a low of 1.0 percent per year compared to the average annual gain in steel of 1.3 percent per year.

One author that has written extensively about topics related to the steel industry is William T. Hogan S.J. of Fordham University. In one of his earlier publications,[39] in addition to covering productivity concepts, he measures the gains in output per manhour in blast and open hearth furnaces from 1920 to 1946. More recently, Hogan has published a number of volumes[40] dealing with the overall steel industry in which he at times includes sections about productivity. He agrees that the B.L.S. figures of output per manhour indicate that steel's lag in productivity is more pronounced than those in the overall private economy and in manufacturing industries in general. But he warns about the biases of B.L.S. figures concerning the steel industry. These biases result from several reasons.[41] Steel industry output is measured in physical units, tons, which does not take into account the shift of production towards lighter steel due to increased demand for these products. By measuring output in tons it does not take into account quality improvements achieved for finished steel. On the input side, it ignored other important inputs such as materials and capital. This results in overestimated productivity gains. Manhours are considered as homogeneous by assuming that every employee hour contributes the same effort, this being a rather invalid assumption.

In a more recent publication,[42] Hogan analyzes the reasons contributing to the productivity lag in the steel industry. Some of these are:

-- Reduced volumes, scheduling problems with increased imports: the relationship between growing output and increased productivity has been demonstrated in other countries. With increased imports the U. S. steel industry facilities have not been operating at desirable output rates. This drags down productivity. Increased imports in stocked sizes has resulted in a greater proportion of more difficult rollings and setups of equipment for the domestic mills.

-- Shift towards lighter steel: This is particularly true with products such as tinplate, structurals, and piping. These products are now lighter than what they used to be, so a measure of output in terms of unweighted tons cannot measure this shift.

-- Higher quality standards: Better production processes and equipment have improved quality that is not measured. More severe inspection standards have contributed in some instances to a reduction of shipments.

-- High technological state of the industry: Due to the high technological level already found in the industry productivity gains have been difficult to achieve.

-- Pollution control expenditures: Increased requirements in capital costs and manpower has been necessary to comply with Government policies regarding pollution control. These do not contribute to increasing output. Other points, treated by Hogan, having detrimental effect on productivity are the expensive construction time, larger break-in periods and more difficult maintenance and repair required by the more sophisticated, electronic and computerized modern steel mills. These factors delay productivity gains derived from new equipment. There is also the problem of balancing facilities. The matching of new equipment with the older existing ones is not always an easy task. On the labor side, rapid increase in turnover rates have required expanded training program for new employees.

Hogan[43] reports on the establishment of plan productivity committees where union representatives and management get together to try to delineate policies focusing on product quality, waste curtailment, reducing absentism,all this for the purpose of improving output per manhour.

As for the prospects for increased productivity he insists on the adequate production volume as a prerequisite. The new capacity being installed should be directed towards eliminating existing bottlenecks and "effective action" will be required to reverse the effect of the factors described above that have been contributing to this productivity lag.

Thompson,[44] another steel industry analyst comments on productivity and increased volume by saying that probably productivity will suffer as production levels increase and reach near capacity levels because marginal equipment, normally used on a standby basis, will come into production, this in a way contradicts Hogan's point of view. The point is also made that due to the ever-closer productivity gaps of other traditional steel producing countries such as Japan, West Germany, France, and Great Britain in respect to the U. S., the comparative inflationary trends among these countries will most likely be the determinant of their relative competitive advantage in the worldwide steem markets.

Other publications have dealt in detail with other aspects related to productivity. On the output side, the demand for steel is closely watched by steel industry analysts, especially the demand coming from the automotive industry, durables manufacturers, and residential and industrial construction. On factors affecting the demand for steel, Hogan dedicates a chapter in one of his publications.[45]

U. S. steel industry labor input has been studied and compared with other countries. Comparative trends of labor cost per unit have been presented in a recent study sponsored by the Government.[46] This and other publications sponsored by the Government and research institutions have reported on trends in raw materials and energy utilzation.[47,48,49,50] Also related to productivity, there are articles forecasting capacity needs and capital costs that will be required to supply future expected demand. This point will be discussed more in detail later during this study

The only formal attempt to measure total productivity in the iron and steel industry, that has been found in the literature is the work done by British authors, J. G. Smith and T. P. Miles.[51] Total productivity measurements are performed for the British Iron and Steel Industry from 1950 to 1960. The output of this measure is defined as the industry's total output in constant base period value terms adjusted by inventory levels. The components of inputs considered are labor, raw materials and fuel, and capital. The labor input is measured in terms of manhours weighted by average hourly earnings of three broad labor classifications. Raw materials are measured by taking consumption of each type of material weighted by their purchase price in base year terms. The two major materials items are iron ore and scrap. Fuels include consumption of core, coal, oil, and electricity. The authors recognized that capital input was difficult to measure. They have estimated the total fixed capital stock at a given time and then applied a base period rate of return to obtain the estimate of capital input. This study concludes that a gain of 3.5 percent per year in labor productivity has been accompanied by a small gain of 0.9 percent per year in material and fuels productivity and a decline of 1.5 percent per year in capital productivity. The net result is that there has been an estimated total productivity increase of 1.5 percent per year.

The British Iron and Steel Industry has published several other articles dealing with concepts and measurement of productivity in the steel industry.[52,53] Others have measured productivity of individual processes and types of equipment used in the steel industry such as blast furnace.[54]

A topic closely related to productivity is the capacity expansions and related capital expenditures that the industry will require in order to be able to supply future expected steel demand. This point is important because the effect of capacity increases on productivity will be analyzed in the experimentation chapter of this study.

David R. Dilley[55] estimates in a 1974 article that the U. S. steel industry would require additions of raw steel capacity of 25 to 30 million tons over and above replacements to keep up with expected demand. Another similar amount is estimated for replacement purposes. These are the estimated requirements in order to meet domestic needs for steel, assuming that imports make up 13 percent of domestic steel supply. Dilley estimates the total need for capital expenditures for additions of new capacity, replacement and pollution control equipment to be an average annual expenditure of $4.5 to $5.0 billion between 1975-1980.

Late in 1976, the U. S. Industrial Outlook[56] mentions that the U. S. steel firms had deferred about 15 percent of its announced capacity additions as a result of the 1975 recession. Despite this reduction, he estimates that approximately 40 million tons of new capacity additions and replacements will be required in order for the U. S. mills to retain their current share in the domestic steel market.

Taub,[57] in early 1977, reports that, in general, capacity expansion studies assume a steel demand rate of growth between 2-2.5 percent per year. This analyst presents a table showing the capacity expansion programs of some of the larger steel companies. It shows additions of 10.5 million tons of new capacity by 1980, and close to 8.5 million tons still under consideration. Taub agrees with the estimates of a 1975 study by A.I.S.I. that estimates added capacity of 30 million tons between 1975 and 1983.

In a recent article, Sharkey[58] recognizes that despite the cyclical nature of the steel industry output, consumption can be assumed to continue to grow at the long term average rate of 2.6 percent per year. Assuming this rate of growth and imports accounting for 13 percent of the market, it would mean shipments by 1982 that will be 16 percent above 1977 volume but still 4.2 percent below the record volume year of 111.5 million tons of shipments in 1973.

CHAPTER III

METHODOLOGY, SCOPE AND LIMITATIONS

Data Sources

The aggregate iron and steel industry data to be used in the study is extracted from the annual statistical reports of the American Iron and Steel Institute, A.I.S.I.[59] This organization publishes every year the most comprehensive and reliable data sources concerning the iron and steel industry operations. Statistical series in the areas of financial, economic, employment, exports, imports, raw steel production, shipments, basic materials, etc., are published year after year in the same format and using the same measurement conventions.

General Measurement Approach

The measurement of productivity, using the composite productivity measures presented in the introductory chapter, will require the following measurement steps:

1. To obtain the following model equations:
   - Time series models for input factors in absolute value terms, for the indexes to be used as deflators and for production.
   - Regression models, in order to obtain empirical relationships relating the annual level of production to the

annual level of shipments and revenues in constant dollar value.

- Regression models relating the level of each input factor in constant value terms, to the annual level of production.

2. The use of absolute or current dollar value model equations for inputs, revenues and indexes to obtain adjusted constant dollar value figures for inputs and revenues. This is accomplished by using the forecasts of the indexes to adjust the forecasts of inputs and revenues. Forecasts for shipments and production do not require adjustments because they are expressed in tons.
3. Computation of the composite productivity measure will be done following two alternative approaches:
   a. Use the input and output forecasted figures obtained from the time series models to compute composite productivity from 1950 to 1976. This approach implicitly assumes that inputs and outputs measures are independent of each other. It only takes into account the time related behavior of each input and output measure.
   b. The second approach uses actual historical data from 1950 to 1975 to obtain empirical relationships between the level of production and the level of inputs and among the outputs themselves. These relationships, obtained through regression analysis, relate each

input factor's constant dollar value to the level of production and to a linear time term. By using the forecasted production level obtained from the time series model and the time period in question, estimates of the level of inputs, shipments and revenues can be obtained through the regression expressions. This approach incorporates the historical empirical relationships among inputs and outputs in addition to taking into account time related behaviors.

4. Composite productivity will be measured from 1950 to 1976 using both of the above described approaches. These will be compared with the composite productivity measure computed from the actual data over the same period of time.

Time Series and Regression Overview

The time series and regression concepts outlined in this section will come mainly from Forecasting and Time Series Analysis[60] and Applied Regression Analysis.[61]

Time Series

Several forecasting techniques assume that random errors are independent random variables. If this assumption is correct, observations will also be independent random variables. Techniques such as exponential smoothing and others based on least squares make this assumption. However, there are time series where successive observations are dependent. A given period's observation might be modified by observations from previous periods. This dependency or correlation between any two observations is called autocorrelation, and the data showing this behavior is referred to as autocorrelated. Techniques for analyzing autocorrelated data have been developed and presented in the Box-Jenkins models.

Consider successive observations of a time series represented by a linear combination of independent random variable ε_t, ε_{t-1}, ε_{t-2}... that come from a probability distribution with mean 0 and variance σ_ε^2. This can be written as:

$$x_t = \mu + \psi_o\varepsilon_t + \psi_1\varepsilon_{t-1} + \psi_2\varepsilon_{t-2} + \ldots \qquad [3\text{-}1]$$

and also in terms of the backward shift operator B, where in general $B^j\varepsilon_t = \varepsilon_{t-j}$ as:

$$x_t = \mu + (\psi_0 B^0 + \psi_1 B^1 + \psi_2 B^2 + \ldots)\varepsilon_t \qquad [3\text{-}2]$$

The sequence of random variables ε_t, ε_{t-1}, ε_{t-2} is called a white noise process. The ψ_j's are constants (parameters) and μ determines the level of the process. Expression [3-1] is normally called a linear filter model. Successive observations x_t are dependent because they are determined from some previous values of ε_i. The linear filter model incorporates a white noise process into a time series.

For practical applications the linear filter model is expressed in other forms, such as the autoregressive (AR) and moving average processes (MA).

The autoregressive process of order p, AR(p), regresses the current observation x_t on previous observations x_{t-1}, x_{t-2}, ... x_{t-p}, and is expressed as:

$$x_t = \xi + \phi_1 x_{t-1} + \phi_2 x_{t-2} + ... + \phi_p x_{t-p} + \varepsilon_t \qquad [3-3]$$

where ϕ_1, ϕ_2 ... ϕ_p are p unknown parameters to be estimated.

A first order autoregressive process, AR(1), is obtained from expression [3-3] with p = 1 as:

$$x_t = \xi + \phi_1 x_{t-1} + \varepsilon_t \qquad [3-4]$$

Similarly, higher order autoregressive processes are obtained by substituting other values of p in expression [3-3].

The moving average process is another special case of the linear filter model where only the first q weights have non-zero values and where the parameters have a negative sign for convenience. The MA(q) models are expressed as:

$$x_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - .... - \theta_q \varepsilon_{t-q} \qquad [3-5]$$

A first order moving average process MA(1) is given by:

$$x_t = \mu + \varepsilon_t - \phi_1 \varepsilon_{t-1}$$

for q = 1 in Equation [3-5] higher order moving average processes can be expressed in similar manner.

Models can also be built by including both autoregressive and moving average terms. Their general form is:

$$x_t = \xi + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \cdots + \phi_p x_{t-p} - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots \theta_q \varepsilon_{t-q} + \varepsilon_t \qquad [3\text{-}6]$$

These are called mixed autoregressive-moving average models of order (p, q), referred to as ARMA(p, q).

Time series are stationary if observations fluctuate around a definable mean and nonstationary if the process has no natural mean and/or slope. The autoregressive-moving average processes described above can be used to model stationary time series and can be modified easily to deal with nonstationary processes. A nonstationary process can be reduced to a stationary one by using successive differencing of the observations. Several differences might be tried in order to obtain a stationary series in both mean and slope. The difference operator is given by $\nabla x_t = x_t - x_{t-1}$ and in terms of the backward shift operator as $\nabla = 1 - B$. In general $\nabla^d = (1-B)^d$ where d is the order differencing.

A general model that includes autoregressive, moving average and differencing and that is useful in representing nonstationary processes is the autoregressive integrated moving average process of order (p, d, q), for short called ARIMA (p, d, q). The general form of this model in terms of the backward shift operator B, is:

$$\Phi_p(B)\nabla^d x_t = \theta_q(B)\varepsilon_t$$

or

$$\nabla^d x_t = \xi + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \cdots + \phi_p x_{t-p} - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \cdots - \theta_q\varepsilon_{t-q} + \varepsilon_t \qquad [3\text{-}7]$$

A particular model of this kind, the ARIMA (2, 1, 2) given by,

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \phi_2(x_{t-2} - x_{t-3}) - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

showed to be very useful by adequately representing several of our input and output series, all of which are nonstationary.

Regression Analysis

Simple linear regression is used to express a straight-line relationship or dependency of one variable on another.

The simple linear regression relationship between a dependent variable x and an independent variable T is given by:

$$x = \beta_0 + \beta_1 T + \varepsilon \qquad [3\text{-}8]$$

The terms β_0 and β_1 are parameters to be estimated through least squares. The estimates of these parameters are usually expressed at b_0 and b_1 and represent the intercept and slope. ε is the random error deviation from the mean.

The case of simple linear regression can be extended to multiple linear regression where it is desired to find a relationship between a dependent variable x and several independent variables $z_1, z_2, z_3, \ldots z_k$. This model can be expressed as

$$x = b_1 z_1 + b_2 z_2 + \ldots + b_k z_k + \varepsilon \qquad [3\text{-}9]$$

where again, $b_1, b_2, \ldots b_k$ are parameters to be estimated and ε is the random error component. This general model form can be used to express any functional relationship that is linear in the parameters.

A commonly used application of regression is to have a dependent variable, say x_t which is a time series and independent variable (s) which are also time series. It is in this context that we will use regression analysis. Functional relationships between inputs and production and between the outputs themselves will be obtained by using the historical data of input and output factors.

For n observations or time periods for the dependent and independent variables time series, we can express Equation [3-9] above, as:

$$x_j = b_1 + b_2 z_{2j} + b_3 z_{3j} + \ldots + b_k z_{kj} + \varepsilon_j \qquad [3\text{-}10]$$

$$j = 1, 2, \ldots, n$$

where $z_{1j} = 1$ and in general z_{ij} is the value taken by the i^{th} independent variable in the j^{th} time period.

Parameters are estimated by least squares and assumes that the random error component ε_j has a mean of zero, a variance σ_ε^2 and that errors are uncorrelated.

Scope and Limitations

1. The study is based on the analysis of aggregate steel industry data. Generally, it is more difficult to pinpoint the factors causing productivity changes at the industry level that at a particular firm level. The higher the level of aggregation, the larger number of factors that come into play and that can cause a particular input or output measure to change.
2. The data used for the four inputs is taken in value terms and adjusted by a single index for each input in order to obtain the adjusted constant dollar value of inputs. There is no attempt to measure inputs and revenues by taking physical units quantities and weigh them by the different unit costs in the case of inputs and unit prices in the case of revenues. The measurement process would have been much more time consuming and would have required an enormous amount of data which is not available at the industry level.
3. The emphasis of the study is in the approach and not so much in the measurement procedure itself. We are more interested in developing a model that would adequately

represent actual historical trends and that could be used to forecast productivity trends for several future periods, than in a model that would emphasize the measurement and adjustment procedures required for input and output factors.

Despite our aggregate measurement procedure, we intend to show that better productivity interpretations can be obtained taking into account several input factors than by considering only the labor input as it is usually done.

4. Some of the data extracted from the A.I.S.I. statistical reports comes from its financial statistics section. The data here presented, includes results of activities into which the iron and steel parent companies might also have interests, and these activities might not be part of the steel industry. It was not possible from the available data to subtract the contribution of these activities. Nevertheless, this study was consistent in treating these series the same way throughout the time interval analyzed.
5. It is important to point out that in productivity analysis, there is no single best measurement approach. The results and conclusions that can be derived from a given model might not be the same than those obtained from other models. In analyzing the results, one should keep in mind the statistical limitations of the measurement procedures and the particular way that inputs and outputs

are treated.

6. Not all the techniques and approaches that were first planned to forecast inputs and outputs proved to be useful. Alternative approaches had to be used at times, in order to obtain more valid models. In forecasting outputs, it was realized that the demand for steel is controlled by factors which are external to the steel industry. A regression experiment was performed to obtain an empirical relationship between the level of shipments taken as dependent variable and various other factors that might influence the demand of steel, taken as independent variables. It was the purpose of this approach to single out the more significant variables related to shipments and then to obtain adequate forecast models for them, from which forecasts of shipments could be found using the regression expression. The regression experiment, which is presented in Appendix II showed rather conclusive results. The problem was in finding adequate forecasts models for the variables that were found to be significant. Without these valid models, shipments could not be predicted without introducing large errors, due to the errors itself in modeling the time series of the independent variables.

In forecasting inputs, techniques other than Box-Jenkins models were also used. These attempts will be outlined in the next chapter.

CHAPTER IV

EXPERIMENTATION AND RESULTS

Time Series Models for Input Factors, Indexes and Production

Absolute (or Current) Dollar Value Input Factors

The models that will be presented in this section are time series models based on Box-Jenkins methods. The exponential smoothing approach was also used but the models obtained by this method were inferior than those obtained by Box-Jenkins method.

In most cases, the optimum smoothing constant obtained in the optimization phase of the exponential smoothing program used was too large, usually greater than 0.5. Larger values of the smoothing constant can result if the data is autocorrelated. The tracking signals in most of the models were rather large and often greater than their appropriate limits. The forecast errors were also larger in the exponential smoothing models than in the Box-Jenkins models. These results implied that exponential smoothing methods using a single smoothing constant (as opposed to adaptive methods) failed to adapt to the characteristics of the several time series.

One of the characteristics of most of these time series is the so called "stickiness" of costs. It is often found that during expansions and recessions, costs do not move up or down in the same proportion that output does. In the case of a recession for example, is not always desirable or possible to immediately lay off workers, cut short materials supplies and other expenditures. There exists a kind of smoothing force, where a given period's level of costs is related to what this level was in the previous period. This means that successive time period observations are autocorrelated. An example of this behavior can be shown by observing the changes in output level and in costs for the recession year of 1975. Domestic raw steel output declined by 20 percent. Total hours worked by steel industry employees were down by 16 percent and the average number of wage and salaried employees fell by only 11 percent. Scrap consumption declined by 23 percent. Iron ore consumed by blast furnaces was down 16 percent. Consumption of fuel oil, natural gas, and electricity declined by 18 percent, 14 percent, and 11 percent, respectively.

For each series of input factor, indexes and production, the selected Box-Jenkins time series model is presented along with two criterias for model performance. Chi-square tests are performed to test the hypothesis that the residuals of the model represent a white noise process. This means that the model obtained has no other definable structure and that the model is adequate. Not being able to reject the hypothesis means that there is no indication that the residuals of the model are other than white noise. Also the residual mean square for each model will be given. In building a model for a particular series, we would normally seek for the lowest possible residual mean square because it means that greater variation is explained by the model.

Absolute value figures for the inputs and revenues are given in millions of dollars and shipments and production in millions of tons. The actual figures published by the American Iron and Steel Institute (A.I.S.I.) have been rounded-off due to input data requirements of the Box-Jenkins programs. All the time series models developed are obtained from two Box-Jenkins programs. One is used for identification and the other for diagnostic checking. For each time series studied, the model's one period ahead forecast and actual values up to 1976 will be presented in plots and tables. A one period ahead forecast is the forecast for period T performed in period T-1, using past actual data observations and residuals. From 1977 to 1986 the forecasts given are also made for one period ahead, but using previous periods forecasts in the models instead of the actual data, as from 1977 to 1986 no actual data is available.

Labor

The series analyzed is total employment cost in absolute dollar value terms for the aggregate industry. These figures are the employment costs that are used in the yearly aggregate iron and steel industry income statement. A.I.S.I. mentions that these figures include all the affiliated interests of the parent companies that submit consolidated statements to them.

Total employment cost per manhours in absolute terms has been increasing at a much larger rate than output per manhour. From 1967 to 1975 indexes of output per manhour had risen about 5 percent and total employment cost per manhour, in absolute value, has gone up by 125 percent. Total employment costs includes wages, salaries and fringe benefits such as: social security taxes, pensions, insurance, savings, and vacation plans, supplemental unemployment benefits and "other" employment costs. During the ten year period 1967-1976 total employment cost in absolute dollar terms has increased by 100.4 percent. This increase results from a 85 percent increase in wages and salaries and an overall 214 percent increase in fringe benefits. Pensions show the largest increase of close to 400 percent between 1967 and 1976.

Due to the increasing nature of the absolute value terms total employment cost series, the process is nonstationary in mean and slope.

Model: ARIMA (2, 1, 2), with

Autoregressive parameters: $\phi_1 = 0.49820$, $\phi_2 = 0.77955$

Moving average parameters: $\theta_1 = 0.71558$, $\theta_2 = 0.56287$

One regular difference.

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \phi_2(x_{t-2} - x_{t-3})$$

$$- \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting

$$x_t = x_{t-1} + 0.49820(x_{t-1} - x_{t-2}) + 0.77955(x_{t-2} - x_{t-3})$$

$$- 0.71558\ \varepsilon_{t-1} - 0.56287\ \varepsilon_{t-2} + \varepsilon_t \qquad [4\text{-}1]$$

Residual mean square = 27.896

Chi-square statistic value:

$$12.90 < \chi^2_{0.05,\ 11} = 19.68 \text{ (Tables)}$$

Plots of this model's one period ahead forecasts or fitted values and actual data are given in Figure 4.1. Table A.1 presents the actual data and forecasts from the time series models selected, for the four input factors.

Materials

The series to be analyzed is the aggregate of materials, supplies and other services that is used by A.I.S.I. in its yearly iron and steel industry income statement. Major raw materials are iron ore and beneficiated iron-bearing materials, coke, limestone, scrap metal, refractories, air and oxygen, other fuels such as coal, fuel oil, tar and pitch, L.P.G., natural gas.

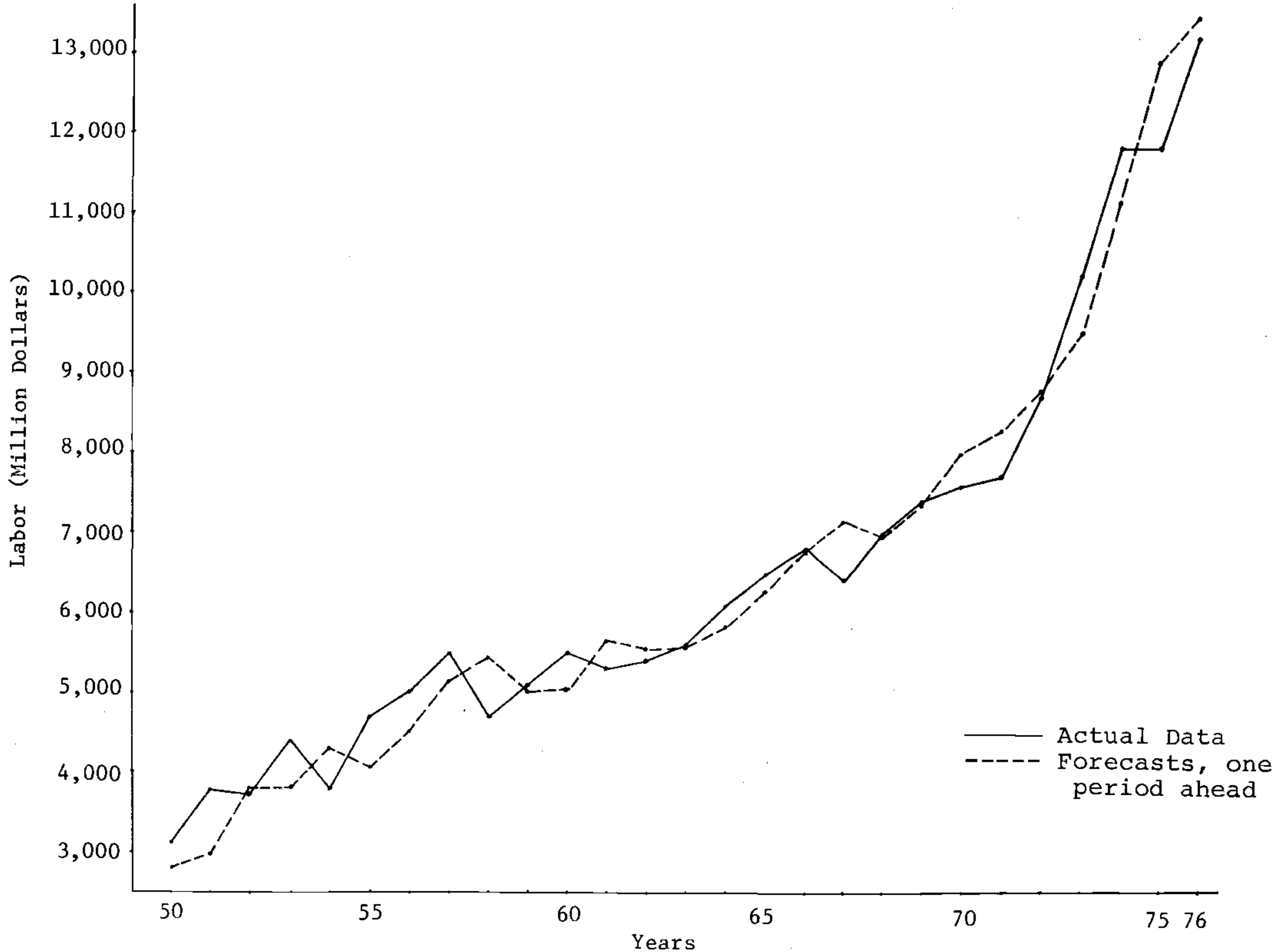

Figure 4.1. Labor: Actual Data and Forecasts (Absolute Value).

There has been a very rapid increase in cost of materials per ton of product since 1973. Figure 4.2 shows that increases from 1956 to 1972 were moderate compared to the steep increase started in 1973. Energy costs have been increasing more rapidly than iron ore costs. The cost of scrap has always been very volatile. Scrap price index based in 1967 (67 = 100) increased from 188.0 in 1973 to 353.2 in 1974 and declined to 245.6 and 259.0 in 1975 and 1976, respectively.

During 1974, 1975 and 1976 the cost of materials, supplies, freight, and other services have been representing 53 percent of those years operating revenues.

Model: ARIMA (2, 1, 2), with:

Autoregressive parameters: $\phi_1 = 0.60016$, $\phi_2 = 0.66098$

Moving average parameters: $\theta_1 = 0.58760$, $\theta_2 = 0.63170$

One regular difference

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \phi_2(x_{t-2} - x_{t-3}) - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting

$$x_t = x_{t-1} + 0.60016(x_{t-1} - x_{t-2}) + 0.66098(x_{t-2} - x_{t-3}) - 0.58760\,\varepsilon_{t-1} - 0.63170\,\varepsilon_{t-2} + \varepsilon_t \qquad [4-2]$$

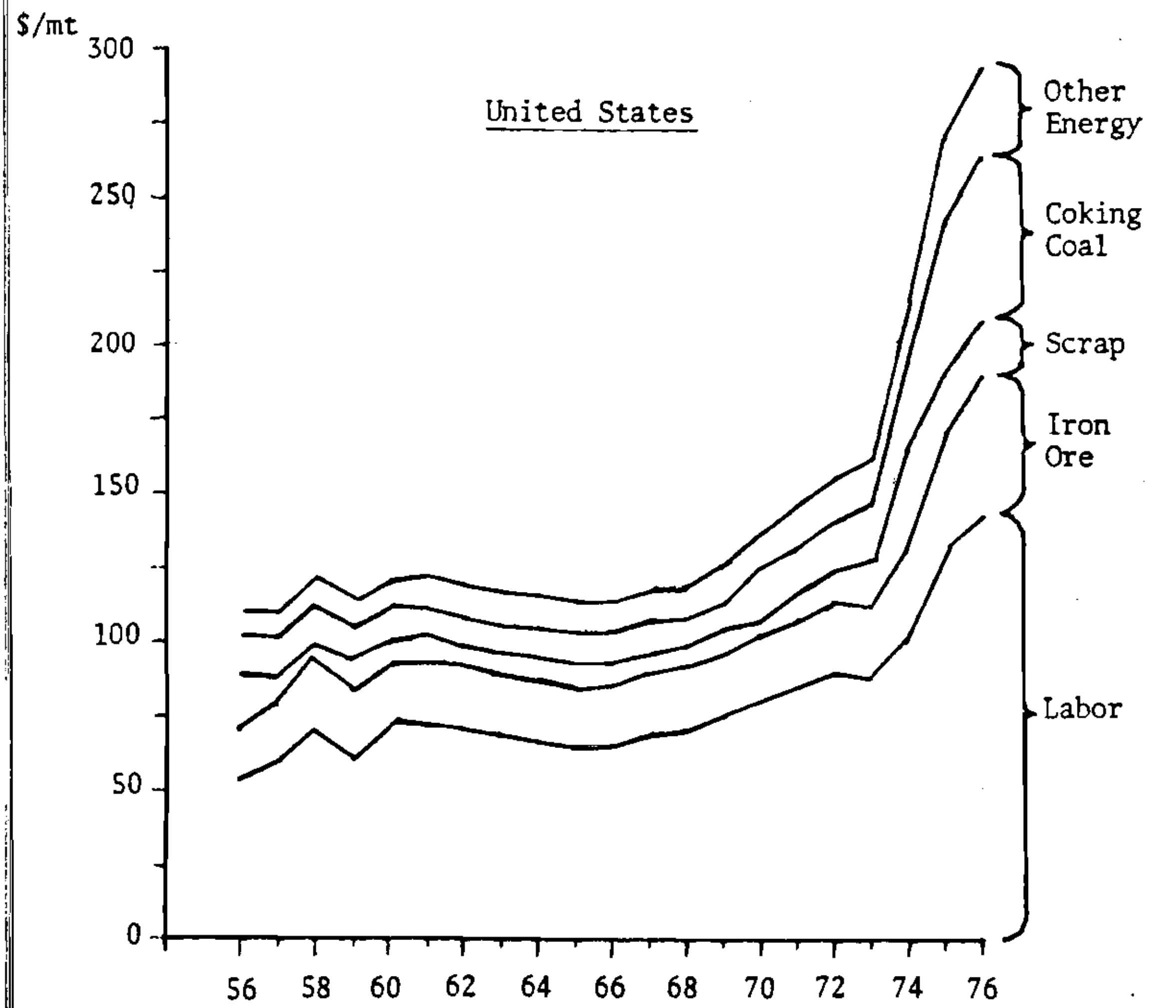

Figure 4.2. Cumulative Unit Costs for Selected Inputs.

Residual mean square = 244.7

Chi-square test:

$$\text{Statistic} = 5.73 < \chi^2_{0.05,\ 11} = 19.68 \text{ (Tables)}$$

Plots of actual data and forecasted values are shown in Figure 4.3.

The larger residual mean square in this model than in the labor model results from the sharp increase in material cost since 1973 or even since 1971, which makes it difficult to the model to adjust quickly to this new trend. Also due to large price increases in materials during 1974 and the following recession in 1975 there was a dip in this cost series from 1974 to 1975 making it again, difficult to the model to adjust quickly.

Electric Energy

Electric energy supplies less than 10 percent of the total steel industry energy requirements in terms of equivalent BTU's. However, the use of electric energy has been increasing in steelmaking due to the larger amounts of electric arc furnaces that have come into operation. The so called mini-steel-plants that have been increasing in number normally operate using electric arc furnaces to melt scrap. These plants and also integrated facilities using more and larger electric furnaces have contributed to the increase of electricity as energy source. At the present time electric arc furnaces produce approximately 20 percent of the raw

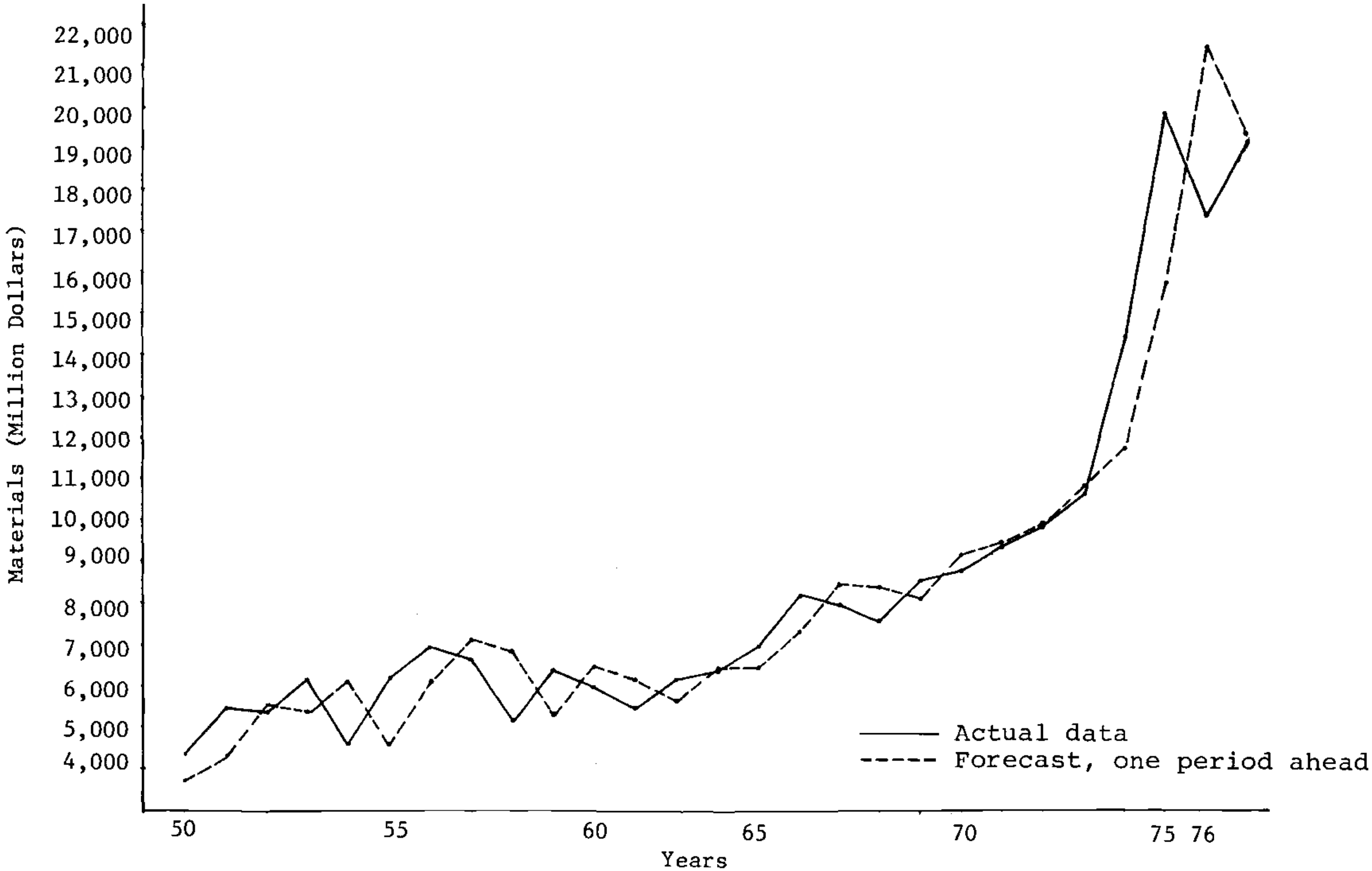

Figure 4.3. Materials: Actual Data and Forecasts (Absolute Value).

steel production, whereas in 1956 they produced only close to 7 percent.

The greater use of electricity in steel and its ever increasing unit cost means that electric energy costs will continue to represent a larger proportion of steelmaking costs.

The electric energy costs have been separated from the previous materials and supplies series in order to observe the increasing electric energy costs apart from other inputs.

The series to be analyzed is the total electric energy consumption by the steel industry. This figure is given by A.I.S.I. in terms of kilowatt-hours. Electricity indexes published by the U. S. Statistical Abstract[57] have been used to convert kilowatt-hours to dollar value.

Model: ARIMA (2, 1,1), with:

Autoregressive parameters: $\phi_1 = 0.68380$, $\phi_2 = 0.78195$

Moving average parameter: $\theta_1 = 1.0405$

One regular difference.

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \phi_2(x_{t-2} - x_{t-3}) - \theta_1\varepsilon_{t-1} + \varepsilon_t \quad [4\text{-}3]$$

Substituting the estimated parameters, we obtain

$$x_t = x_{t-1} + 0.68380(x_{t-1} - x_{t-2}) + 0.78195(x_{t-2} - x_{t-3}) - 1.0405\ \varepsilon_{t-1} + \varepsilon_t$$

Residual mean square = 17.80

Chi-square test:

$$\text{Statistic} = 12.89 < \chi^2_{0.05,\ 12} = 21.03 \text{ (Tables)}$$

Actual and forecasted values are shown in Figure 4.4.

Capital

The series to be analyzed is the gross fixed capital or fixed assets. It represents the gross stock value of plant and equipment in absolute dollar value. This series shows how the industry's capital stock is increasing. The yearly figures of this series are taken from the overall iron and steel industry balance sheet.

Model: ARIMA (1, 1, 0), with:

Autoregressive parameter: $\phi_1 = 0.99827$

One regular difference.

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \varepsilon_t$$

and substituting the estimated parameter ϕ_1

$$x_t = x_{t-1} + 0.99827(x_{t-1} - x_{t-2}) + \varepsilon_t \qquad [4\text{-}4]$$

Residual mean square = 28.22

Chi-square test:

$$\text{Statistic} = 4.79 < \chi^2_{0.05,\ 14} = 23.68 \text{ (Tables)}$$

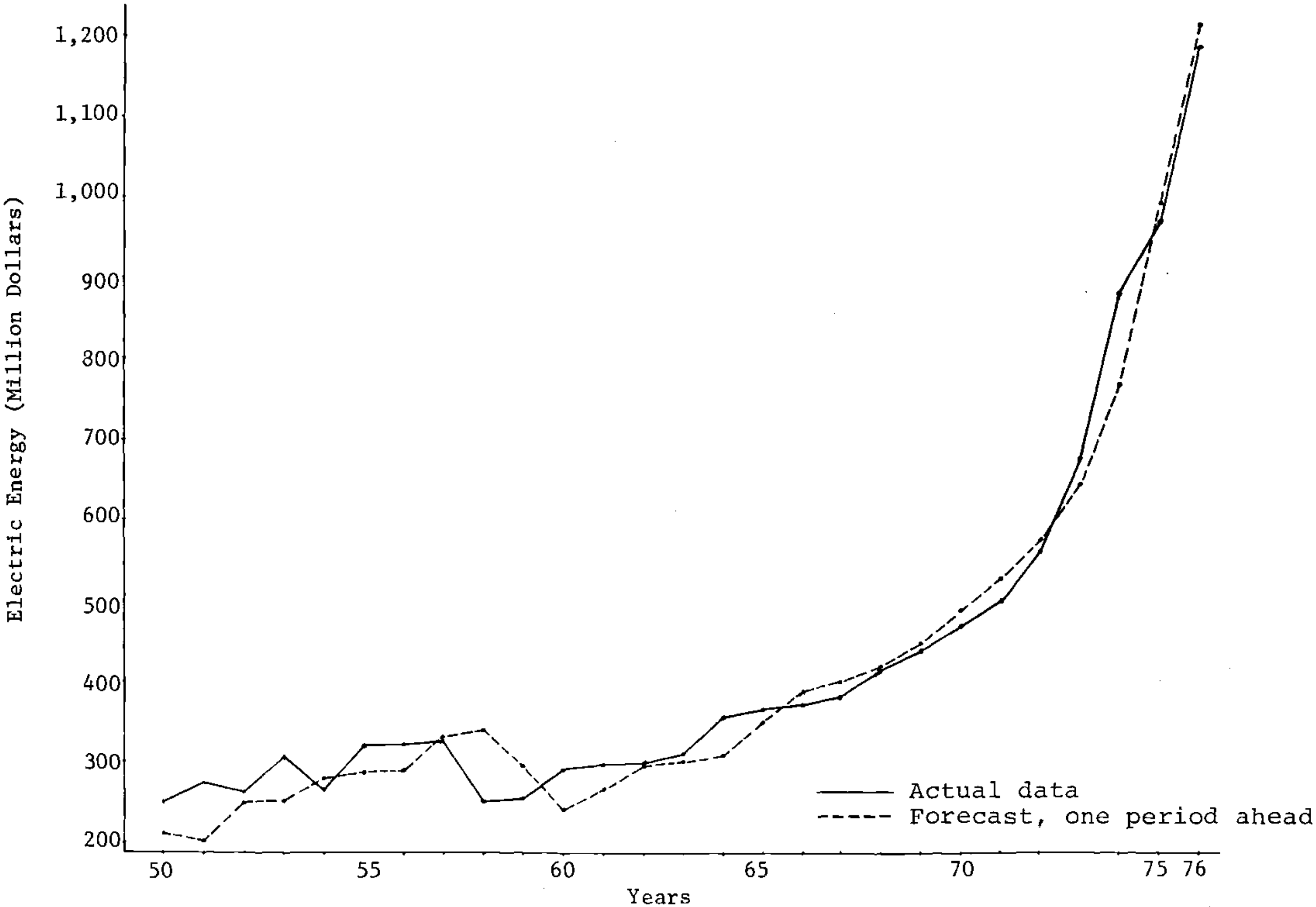

Figure 4.4. Electric Energy: Actual Data and Forecasts (Absolute Value).

Plots of actual and forecasted values are given in Figure 4.5. This times series resembles quite closely a straight line plot, so a regression equation with fixed capital as dependent variable and time as independent could have been used to model this series.

Indexes

We now present the models obtained for four index series that will be used as deflators of the absolute value figures. These series are also given in the A.I.S.I. statistical reports[54] and are published by the Bureau of Labor Statistics. The four series will have 1967 as their base year, so for these series 1967 = 100. Table A.2 presents the actual data and forecasts for the four indexes series analyzed.

Steel Price Index

The index series analyzed is the total steel mill products price index series. This is a composite index for finished and semifinished products, but its values are very much the same as the series of prices of finished products alone.

Model: ARIMA (2, 1, 2) with:

Autoregressive parameters: $\phi_1 = 1.1073$, $\phi_2 = -0.13267$

Moving average parameter: $\theta_1 = 0.71738$, $\theta_2 = 0.64085$

One regular difference.

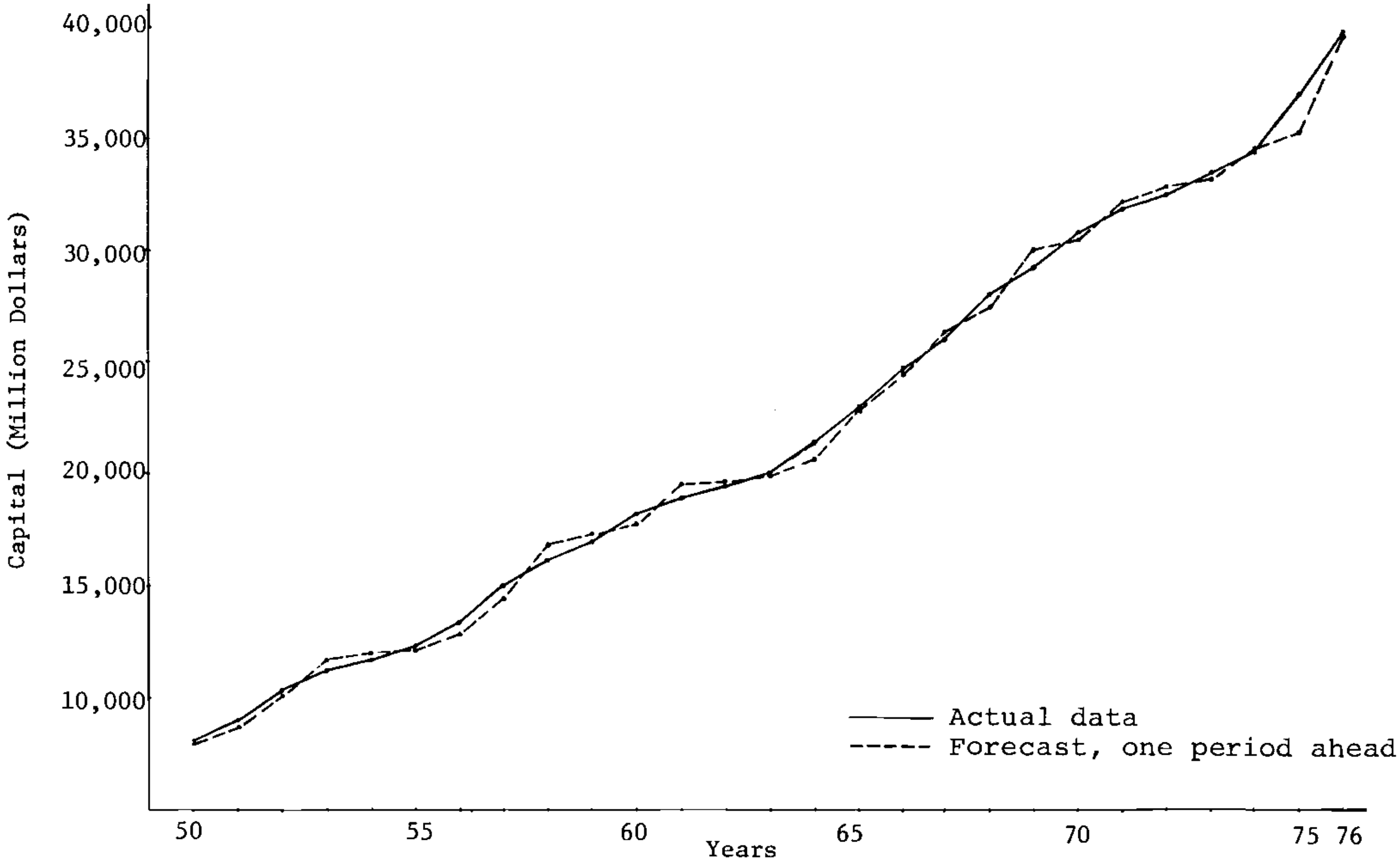

Figure 4.5. Capital: Actual Data and Forecasts (Absolute Value).

General Form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \phi_2(x_{t-2} - x_{t-3}) - \theta_1\varepsilon_{t-1}$$

$$- \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting

$$x_t = x_{t-1} + 1.1073(x_{t-1} - x_{t-2}) + (-0.13267)(x_{t-2} - x_{t-3}) \qquad [4-5]$$

$$- 0.71738\ \varepsilon_{t-1} - 0.64085\ \varepsilon_{t-2} + \varepsilon_t$$

Residual mean square = 33.66

Chi-square test:

Statistic = 9.70 < $\chi^2_{0.05,\ 11}$ = 19.68 (Tables)

Plots of this series and actual values are given in Figure 4.6.

Labor Index

The series analyzed is the index of total employment cost per hour. This includes the regular straight time plus premiums and fringe benefits for wage employees. It was not possbile to find a similar index for wage and salary employees but this should not cause any serious problems in this analysis.

The series increases in a fairly constant rate from 1951 to 1970. Starting in 1971, there is a steep increase in the index.

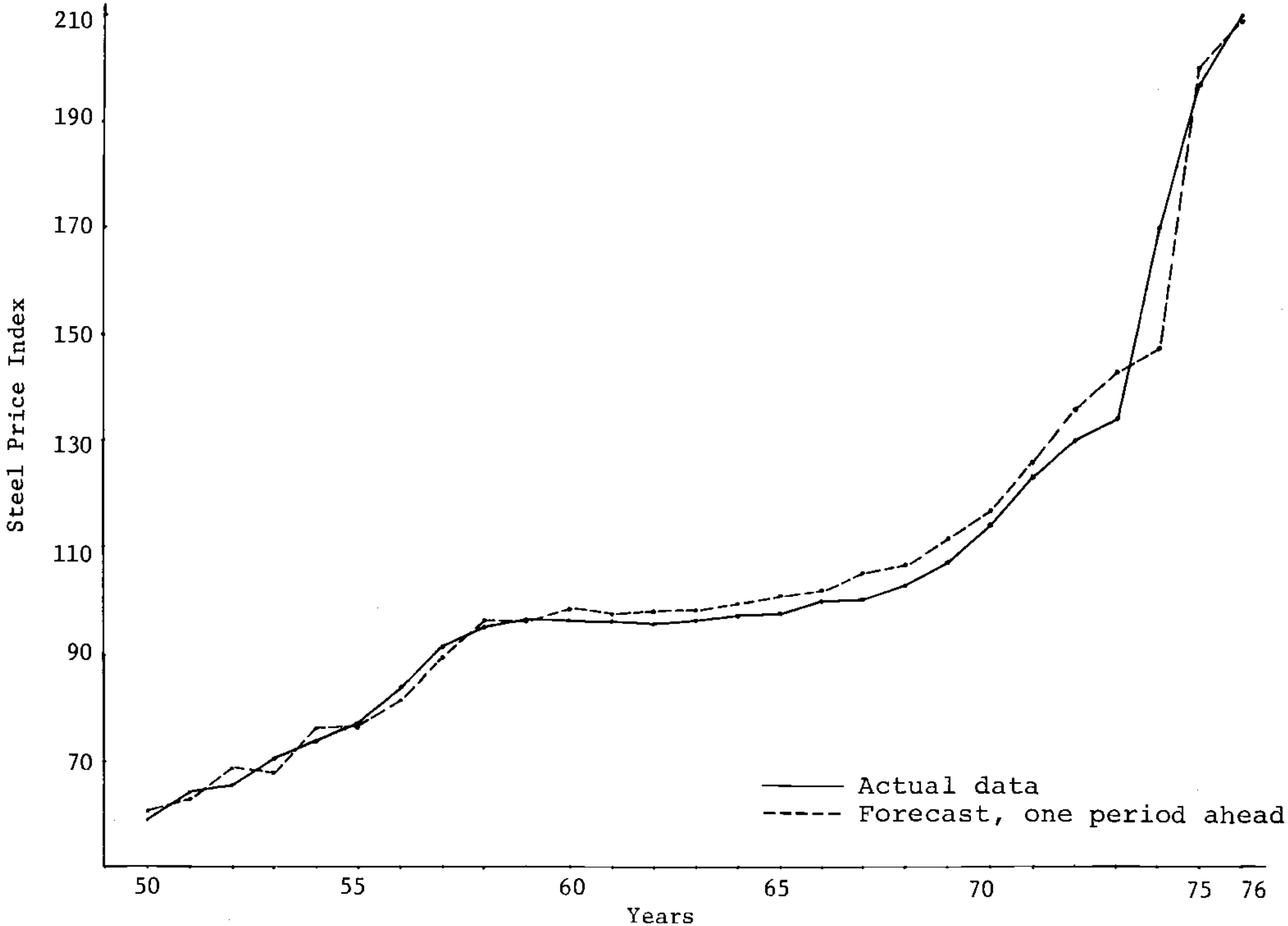

Figure 4.6. Steel Price Index: Actual Data and Forecasts.

Model: ARIMA (2, 2, 2), with:

Autoregressive parameters: $\phi_1 = 0.11513$, $\phi_2 = 0.48677$

Moving average parameters: $\theta_1 = 0.45375$, $\theta_2 = 1.0384$

Two regular differences.

General form:

$$x_t = 2x_{t-1} - x_{t-2} - \phi_1(2x_{t-2} - x_{t-1} - x_{t-3})$$
$$- \phi_2(2x_{t-3} - x_{t-2} - x_{t-4}) - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting parameters:

$$x_t = 2x_{t-1}-x_{t-2}-0.11513(2x_{t-2}-x_{t-1}-x_{t-3})$$
$$-0.48677(2x_{t-3}-x_{t-2}-x_{t-4})-0.45375\varepsilon_{t-1}-1.0384\varepsilon_{t-2}+\varepsilon_t \qquad [4-6]$$

Residual mean square = 15.06

Chi-square test:

Statistic = 8.53 < $\chi^2_{0.05,\ 11}$ = 19.68 (Tables)

Figure 4.7 shows actual and forecasted values.

<u>Industrial Commodities Index</u>

This index is also taken from the B.L.S. and given in the A.I.S.I. statistical reports.[54] Due to the great variety of raw materials and types of equipment used in the steel industry, aggregate indexes have to be used to deflate these series. The industrial commodities index is used as deflator of the materials and fixed capital series.

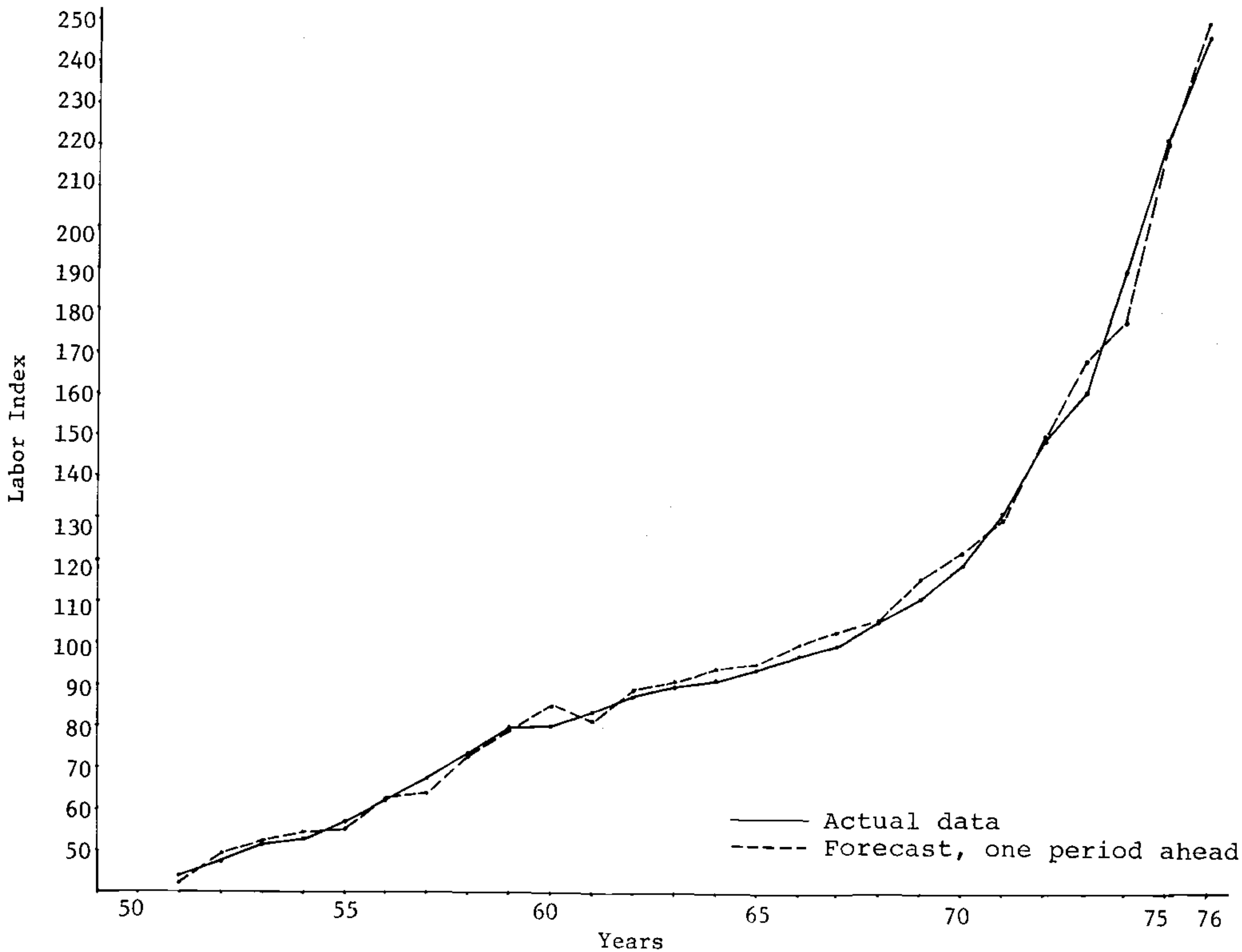

Figure 4.7. Labor Index: Actual Data and Forecasts.

Model: ARIMA (2, 1, 2) with

Autoregressive parameters: $\phi_1 = 0.85163$, $\phi_2 = 0.34916$

Moving average parameters: $\theta_1 = 0.43338$, $\theta_2 = 0.78701$

One regular difference.

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) + \phi_2(x_{t-2} - x_{t-3}) - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting

$$x_t = x_{t-1} + 0.85163(x_{t-1} - x_{t-2}) + 0.34916(x_{t-2} - x_{t-3}) = 0.43338\ \varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t \qquad [4-7]$$

Residual mean square = 18.23

Chi-square test:

Statistic = $1.56 < \chi^2_{0.05,\ 11} = 19.68$ (Tables)

Actual and fitted values are shown in Figure 4.8.

Electric Energy Index

This index series was computed using the series of electricity cost per kilowatt-hour for industry, published by the U. S. Statistical Abstract.[57] The series of cost per kilowatt-hour has been used to convert kilowatt-hour consumption figures given by A.I.S.I. to absolute value terms.

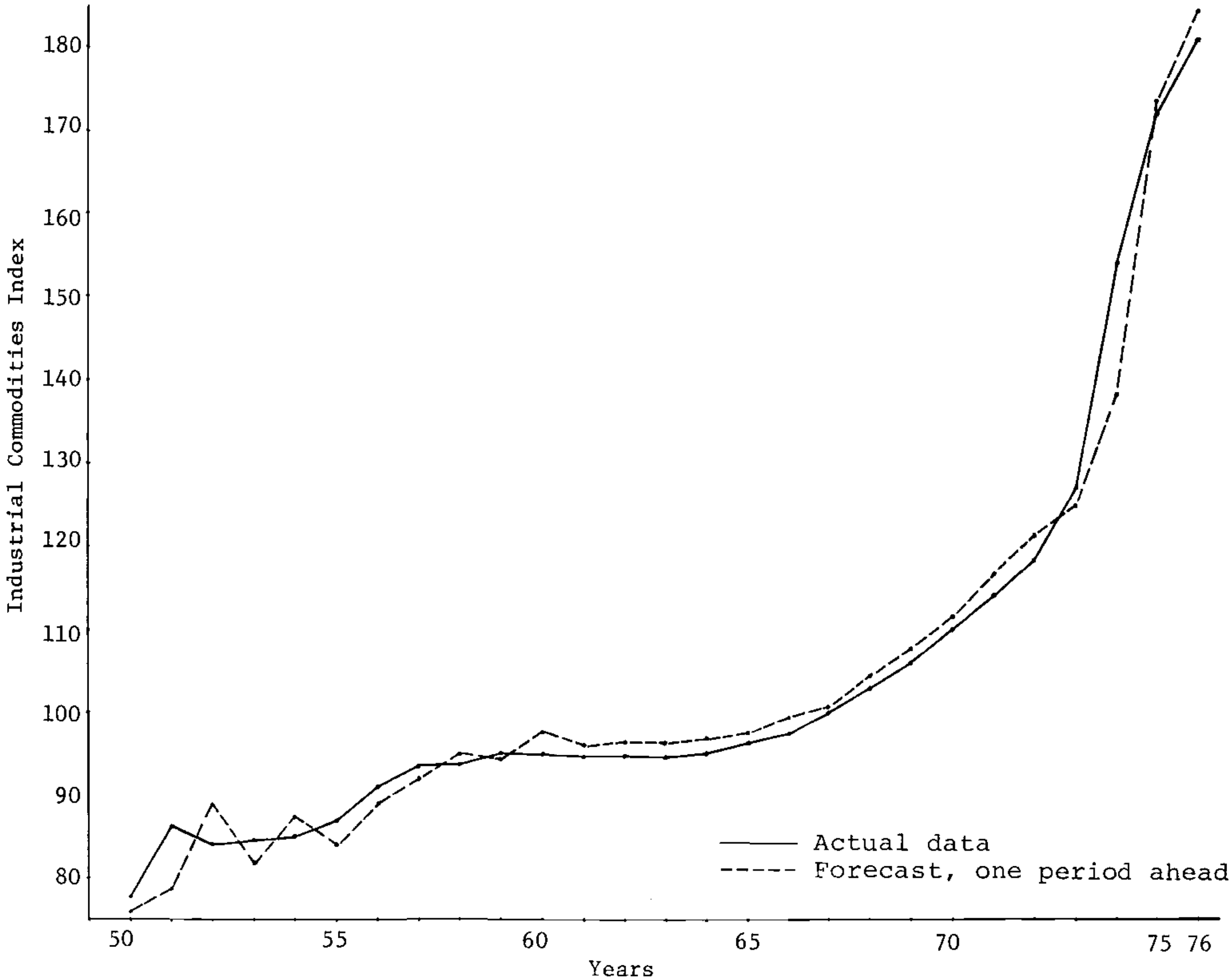

Figure 4.8. Industrial Commodities Index: Actual Data and Forecasts.

Model: ARIMA (1, 1, 2), with:

Autoregressive parameter: $\phi_1 = 1.2762$

Moving average parameters: $\theta_1 = 0.32239$, $\theta_2 = 0.72243$

One regular difference.

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} - x_{t-2}) - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting parameters:

$$x_t = x_{t-1} + 1.2762(x_{t-1} - x_{t-2}) - 0.32239\ \varepsilon_{t-1} - 0.72243\ \varepsilon_{t-2} + \varepsilon_t \qquad [4\text{-}8]$$

Residual mean square = 51.66

Chi-square test:

Statistic = 1.38 $< \chi^2_{0.05,\ 12} = 21.03$ (Tables)

Figure 4.9 shows plots of actual and forecasted values for the index of cost per kilowatt-hour used as the electric energy index.

Production

The series analyzed is raw steel production in terms of tons.

Steel industry output has been traditionally cyclical in nature. A time series approach to model production has been used to observe if it was possible to incorporate into the model its historical cyclical behavior. However, it is

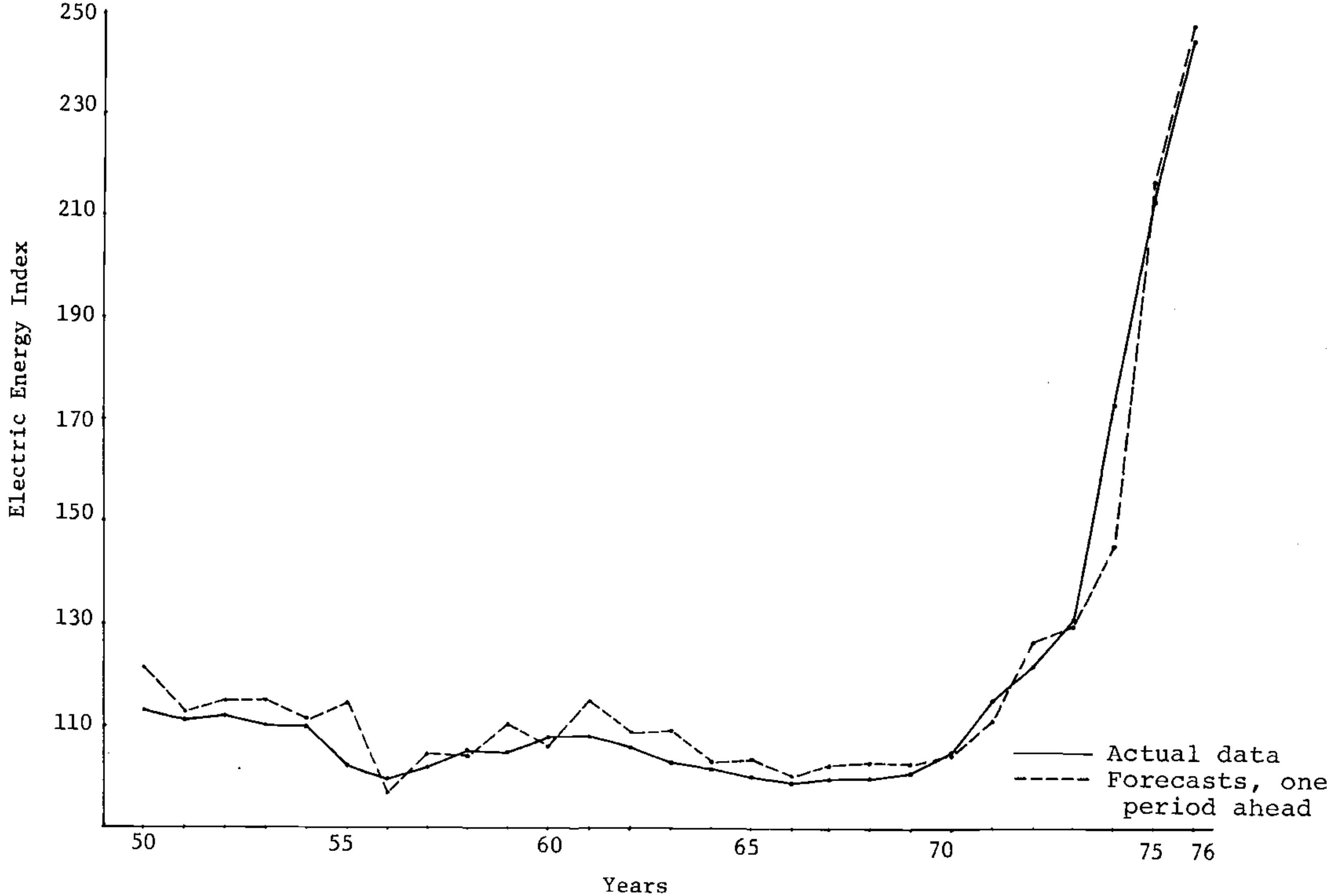

Figure 4.9. Electric Energy Index: Actual Data and Forecasts.

recognized that the level of output measures are affected mainly by demand factors which are external to the steel industry. There may be cases where more adequate models might be developed by studying the effect of these demand factors on the particular output measure than by taking the output measure as it relates to time. The problem is that one requires forecast models for the time series of demand factors, and if these are difficult to model, it will introduce additional error in the forecasts of the output factor of interest.

Model: ARIMA (2, 1, 2), with:

Autoregressive parameters: $\phi_1 = 0.10204$, $\phi_2 = -1.0841$

Moving average parameters: $\theta_1 = 0.30738$, $\theta_2 = -0.87355$

One regular difference.

General form:

$$x_t = x_{t-1} + \phi_1(x_{t-1} = x_{t-2}) + \phi_2(x_{t-2} - x_{t-3})$$
$$- \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} + \varepsilon_t$$

Substituting parameters:

$$x_t = x_{t-1} + 0.10204(x_{t-1} - x_{t-2}) + (-1.0841)(x_{t-2} - x_{t-3})$$
$$- 0.30738\ \varepsilon_{t-1} - (-0.87355)\ \varepsilon_{t-2} + \varepsilon_t \qquad [4-9]$$

Residual mean square = 185.47

Chi-square test:

Statistic = 5.75 $< \chi^2_{0.05,\ 11} = 19.68$ (Tables)

Actual and forecasted plots are given in Figure 4.10 and this data is presented in Table A.3.

From the plots we notice that the model is able to account for the cyclical behavior of the series. At earlier periods, however, there is a one period lag in the increases and decreases of the model as compared to the actual values. This results because in earlier periods most actual value increases are followed by decreases and vice versa. This makes it very difficult for the model to adjust to these changes. However, from 1963 on, this one period lag disappears and the model does a much better job in representing increases and decreases of the actual data. It is evident from the forecasts made from 1976 into the future that the model has been able to take into account the cyclical behavior of the series.

Regression Models for Shipments and Revenues

The approach used to analyze shipments and revenues series was to obtain empirical relationships linking shipments to production and revenues to shipments. This approach was chosen rather than the time series analysis used so far, based on the fact that shipments differ from production by the amount of inventories plus the losses in transforming of raw steel to finished products, which is usually within certain limits. It is then legitimate to believe that an adequate relationship can be obtained between shipments and production. Similarly, it is legitimate to expect a relationship between shipments and revenues, because for other

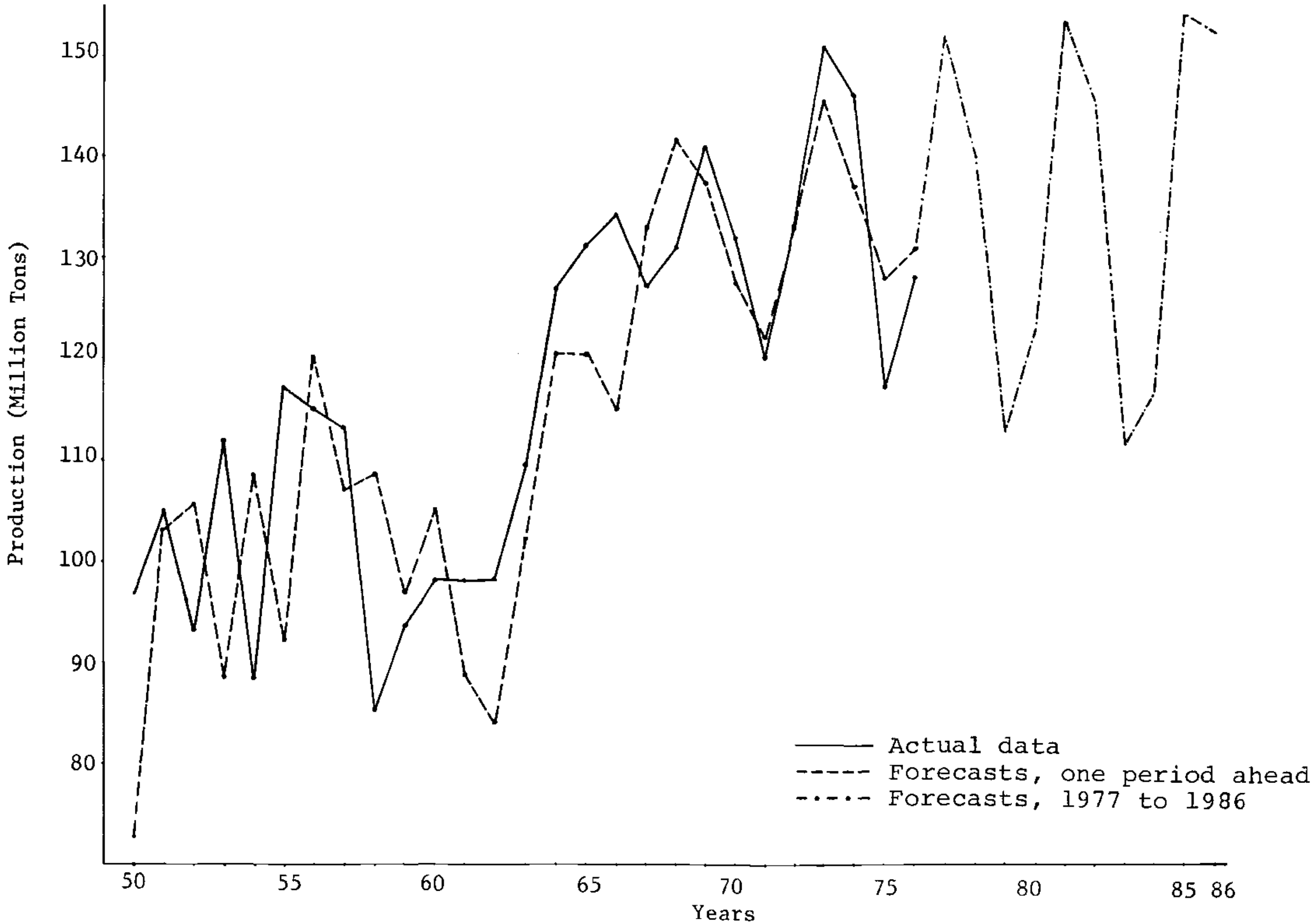

Figure 4.10. Production: Actual Data and Forecasts.

than a few adjustments revenues represent the value of shipments.

The results presented for these regression models and all other regression models obtained in this study are obtained from the SPSS package programs.[62]

Shipments

This expression is obtained by using actual production and shipments series from 1950 to 1975. Shipments are taken as dependent variable and production as the independent variable.

Model:

$$(\text{Shipments}) = 4443.72 + 0.6687\ (\text{Production}) \qquad [4\text{-}10]$$

The parameters obtained confirm that shipments level are generally close to 70 percent of the production level because the 30 percent difference represent inventories and production losses.

$r_{SHIPT,\ PROD} = 0.966$. This large simple correlation coefficient between shipments and production confirm the linear association between the two series.

$R^2 = 93.44$ percent, is also large, meaning that 93.44 percent of the variation in the shipment series is explained by the production series.

Actual and predicted values are shown in Table 4.1.

Revenues

Similarly, the relationship between revenues and shipments was obtained from the actual data of those two series with revenues as dependent variable and shipments as independent variable. In this case, a better model was obtained by including an additional independent variable, a T term representing a linear time effect. The inclusion of the linear time term is motivated by the fact that the time sequence plot of the residuals showed a trend in the sign and magnitude of the residuals. Revenues series is analyzed in constant 1967 dollar value by adjusting the absolute value revenue series by the steel price index for each year.

Model

$$(\text{Revenues}) = 2271.38 + 0.1989\ (\text{Shipments}) - 127.14\ (\text{Time, T}) \quad [4\text{-}11]$$

where shipments is expressed in thousands of tons, and T is the time period number. Simple correlation coefficients

$$r_{\text{Rev, Shipt}} = 0.887$$

$$r_{\text{Rev, Time}} = 0.355$$

$$R^2 = 89.89 \text{ Percent}$$

The inclusion of the linear term in time, T, is appropriate because increases R^2 from 78 percent to close to 90 percent and reduces the mean square error by 50 percent, compared to the model without the T term. The negative sign of the time parameter indicates that as time progresses during the estimation interval of 1950 to 1975, less revenues in constant dollars are being obtained from a given level of

Table 4.1. Shipments and Revenues Actual and Predicted Data.

	Shipments (Millions of Tons)		Revenues (Millions of Dollars) (Constant 1967 Values)	
Year	Actual	Predicted [Eq. - 4-10]	Actual	Predicted [Eq. - 4-11]
1950	72.232	69.198	15,968.9	16,512.5
1951	78.929	74.791	18,409.4	17,717.5
1952	68.004	66.745	16,519.7	15,417.2
1953	80.152	79.077	18,569.5	17,706.5
1954	63.153	63.498	14,272.2	14,197.9
1955	84.717	82.706	18,083.2	18,360.2
1956	83.251	81.489	18,091.3	17,941.5
1957	79.895	79.816	16,850.5	17,146.8
1958	59.914	61.454	13,097.1	13,045.1
1959	69.377	66.931	14,599.7	14,800.3
1960	71.149	70.165	14,587.3	15,025.6
1961	66.126	69.986	13,690.2	13,899.3
1962	70.552	70.196	14,445.2	14,652.6
1963	75.555	77.507	15,008.0	15,520.6
1964	84.945	89.419	16,661.3	17,261.3
1965	92.666	92.352	18,230.6	18,670.0
1966	89.995	94.117	18,271.5	18,011.6
1967	83.897	89.511	16,693.9	16,671.5
1968	91.856	92,352	18,024.2	18,127.5
1969	93.877	98.906	17,704.4	18,402.4
1970	90.798	92.387	16,675.3	17,662.8
1971	87.038	84.984	16,414.4	16,787.7
1972	91.805	93.542	17,151.0	17,608.8
1973	111.430	105.283	21,249.0	21,385.4
1974	109.472	101.887	22,202.9	20.868.8
1975	79.957	82.442	16,807.2	14,870.6

shipments.

Actual and predicted values are presented in Table 4.1.

Computation of Input and Output Factors in Constant Dollar Values

At this point, times series models have been created for the four input factors considered and also for the four indexes that will be used to deflate the absolute value figures, to yield the constant dollar value terms necessary for productivity computations. The three output factors considered do not require further adjustment. Production and shipments are given in terms of tons, and revenues obtained from the linear relationship to shipments and time is already given in constant value terms, as was explained earlier.

All the absolute value series at this point are deflated to 1967 constant dollar values. The labor input given by the total employment series is deflated by the series of index of employment cost per hour. Materials, supplies and other services is deflated by the series of industrial commodities index. Electric energy cost series is deflated by the series of the index of cost of kilowatt-hours.

To adjust capital to constant dollar value a different procedure is required. The 1967 gross capital stock is taken as a base, and additions or reductions to this amount of stock are added or subtracted in constant dollar value by adjusting them by the series of industrial commodities index.

Two sets of results in constant 1967 dollar values are presented. One set for the actual historical data in Table 4.2 and the other for figures obtained by the time series models in Table 4.3. Output factors figures are also given in these tables. In Table 4.3, obtained from forecasts, the shipments and revenues series are obtained by using the two regression expressions Equations [4-10] and [4-11] relating shipments to production and revenues to shipments plus the linear T term. Production is forecasted from the ARIMA (2, 1, 2) model given in Equation [4-9]. These forecasts are used in Equation [4-10] that relates shipments to production and enables the prediction of shipments. The predicted shipments and the time period number are used in Equation [4-11] to predict revenues in constant 1967 value terms.

Regression Models for Input Factors

In this approach, the input factors are related to an output factor through relationships obtained using regression. Using the series of actual data, expressions are obtained that relate each input factor to production. It can be assumed that the production level at a given year is an important factor determining the level of the inputs required in that year. If this assumption is reasonable, it is expected to obtain better models for the input factors through a directly related output factor such as production,

Table 4.2. Input and Ouput Factors: Actual Data Constant Value Terms.*

	Inputs				Outputs		
Year	Labor	Materials	Electric Energy	Capital	Shipments	Production	Revenues
1950	7,857.36	5,584.23	221.52	6,713.15	72.232	96.836	15,968.86
1951	8,622.97	6,373.75	247.99	7,896.19	78.929	105.200	18,409.38
1952	7,780.08	6,422.35	233.03	9,436.03	68.004	93.168	16,519.72
1953	8,726.32	7,178.77	180.40	10,393.35	80.152	111.610	18,569.22
1954	7,363.64	5,385.76	239.38	10,946.06	63.153	88.312	14,272.22
1955	8,233.39	7,056.04	312.90	11,635.13	84.717	117.036	18,083.16
1956	8,184.06	7,710.13	321.84	12,939.60	83.251	115.216	18,091.29
1957	8,177.51	7,228.83	321.06	14,765.54	79.895	112.715	16,850.54
1958	6,492.82	5,603.31	237.79	15,883.81	59.914	85.255	13,097.05
1959	6,441.10	6,756.56	249.98	16,653.54	69.377	93.446	14,599.69
1960	6,893.77	6,307.45	271.97	18,064.77	71.149	98.282	14,581.33
1961	6,386.28	5,831.22	273.32	18,760.97	66.126	98.014	13,690.21
1962	6,278.12	6,464.77	279.89	19,274.47	70.552	98.328	14,445.20
1963	6,277.16	6,517.95	302.07	19,995.91	75.555	109.261	15,008.00
1964	6,706.12	7,382.98	349.07	21,411.46	84.945	127.076	16,661.28
1965	6,931.14	8,377.59	360.29	23,004.51	92.666	131.462	18,230.56
1966	6,993.12	8,166.09	376.30	24,670.50	89.995	134.101	18,271.49
1967	6,496.40	7,453.20	381.81	26,054.30	83.897	127.213	16,693.90
1968	6,654.16	8,377.56	414.57	28,006.89	91.856	131.462	18,024.20
1969	6,633.36	8,268.49	434.65	29,204.44	93.877	141.262	17,704.38
1970	6,425.40	8,328.09	445.31	30,580.87	90.798	131.514	16,675.33
1971	5,922.49	8,723.62	436.89	31.475.86	87.038	120.443	16,414.39
1972	6,070.91	9,064.97	463.04	32,112.50	91.805	133.241	17,151.00
1973	6,320.51	11,378.35	516.48	32,881.70	111.430	150.799	21,248.99
1974	6,215.15	12,939.08	509.64	33,477.17	109.472	145.720	22,202.94
1975	5,338.32	10,130.38	455.01	35,049.24	79.937	116.642	16,807.20
1976	5,381.77	10,456.35	487.71	36,574.69	89.447	128.000	17,222.89

*Millions of dollars and millions of tons.

Table 4.3. Input and Output Factors: Forecasted and Predicted Data, Constant Value Terms.*

	Inputs				Outputs		
Year	Labor	Materials	Electric Energy	Capital	Shipments	Production	Revenues
1950	6,623.44	4,894.18	173.17	6,546.50	53.051	72.690	12,696.19
1951	6,646.57	5,422.05	179.41	7,560.44	73.319	103.000	16,600.25
1952	7,115.37	6,281.08	217.90	9,129.31	75.125	105.700	16,832.38
1953	7,204.81	6,622.66	225.97	11,085.06	63.683	88.590	14,429.54
1954	7,608.06	7,068.57	251.48	11,427.92	77.064	108.600	16,693.82
1955	7,440.72	5,541.30	250.87	11,665.59	66.024	92.090	14,640.77
1956	7,041.10	6,900.18	298.37	12,448.94	84.821	120.200	18,252.39
1957	7,494.37	7,754.10	317.80	14,188.26	75.994	107.000	16,369.59
1958	7,427.99	7,195.29	325.94	16,607.02	76.663	108.600	16,375.45
1959	6,574.75	5,659.78	268.18	17,136.96	69.254	96.920	14,774.62
1960	5,983.57	6,704.23	225.75	17,649.20	74.657	105.000	15,722.16
1961	6,795.88	6,451.38	231.48	19,521.27	63.837	88.820	13,443.01
1962	6,314.73	5,881.38	273.19	19,624.90	60.607	83.990	12,673.46
1963	6,196.52	6,561.01	276.60	19.935.65	72.784	102.200	14,968.33
1964	6,214.86	6,680.42	302.81	20,657.52	84,821	120.200	17,235.27
1965	6,545.36	7,487.99	330.72	22,906.78	85.423	121.100	17,227.83
1966	6,780.19	8,537.15	386.14	24,513.21	81.210	114.800	16,262.76
1967	6,936.05	8,414.10	391.79	26,400.00	93.180	132.700	18,516.40
1968	6,671.36	7,766.73	405.34	27,451.62	99.064	141.500	19,559.70
1969	6,350.91	8,557.62	436.16	29,867.98	96.189	137.200	18,860.64
1970	6,414.24	8,530.47	467.30	30,226.40	89.569	127.300	17,416.76
1971	6,380.95	8,600.86	476.37	31,771.46	86.091	122.100	16,597.99
1972	5,728.55	8,960.40	457.08	32,349.02	93.581	133.300	17,960.51
1973	5,531.23	9,358.16	498.77	32,856.73	101.806	145.600	19,469.32
1974	6,057.37	11,454.41	530.97	33,797.40	95.988	136.900	18,185.04
1975	5,655.11	12,491.31	459.11	34,260.90	89.970	127.900	16,860.86
1976	5,378.15	10,476.71	492.31	36,590.60	91.909	130.800	17,119.44
1977	5,331.60	10,752.96	504.08	38,099.11	106.026	151.911	19,800.20
1978	5,451.61	10,964.26	522.79	39,379.90	98.051	139.984	18,086.67
1979	5,608.65	11,170.43	537.57	40,538.92	79.903	112.845	14,349.93
1980	5,837.76	11,385.56	552.97	41,583.43	86.697	123.006	15,574.25
1981	6,120.91	11,598.38	566.65	42,521.04	107.064	153.463	19,498.09
1982	6,467.87	11,813.25	579.84	43,359.50	101.777	145.556	18,319.25
1983	6,877.03	12,026.44	591.86	44,106.60	79.158	111.731	13,693.19
1984	7,355.12	12,238.88	603.23	44,770.18	82.582	116.851	14,247.12
1985	7,906.24	12,449.36	613.84	45,357.82	107.452	154.043	19,066.64
1986	8,538.01	12,657.70	623.87	45,876.83	106.278	152.287	18,705.93

*Millions of dollars and millions of tons.

than through time series alone. Previously, in the time series approach, it was observed how each factor changes through time, but the factors that cause these changes are not explicitly considered. In this second approach, we have explicitly considered an output factor such as production and use it as independent variable. In building these expressions, better models are obtained by adding a linear time term as it was in the case with revenues, previously discussed. This means that there is an additional time effect when production is the only independent variable considered. These expressions are developed by using the actual data in constant 1967 dollar values. The forecasts for production, in thousands of tons, and the time period number can be used in these expressions to predict the inputs in constant dollar value from which productivity calculations can be made. It is important to note that these expressions are obtained from the historical data from 1950 to 1975. These models must be used with caution for extrapolating beyond 1975, because one is implicitly assuming that the same relationships will hold in the future. As this fact can seldom be assured one should make the effort to recompute new model parameters as new observations become available. In this study the assumption is made that the relationships will hold for the next eleven year period from 1976 to 1986. This will permit to predict productivity during that time span.

Labor

$$(\text{Labor}) = 4927.074 + 0.03625\ (\text{Production}) - 162.213\ (T) \qquad [4\text{-}12]$$

with R^2 = 93.12 percent.

The inclusion of the T term increases the R^2 from 68 percent to 93.12 percent and reduces the mean square error from 267,138.5 to 60,085. The negative sign in the time coefficient means that given that the production factor is already included in the model, there is an additional negative linear time effect, indicating that the level of labor in constant dollars had decreased with time during the 1950 to 1976 time interval that has been used to estimate the parameters. This decreasing effect can be observed in Table A.4. This result clearly shows the importance of restricting extrapolations with regression to only few periods beyond the time interval used to estimate the parameters. As in this case, the model could eventually predict zero and negative labor costs if indefinitely large extrapolations are considered.

Materials

$$(\text{Materials}) = 459.756 + 0.5128\ (\text{Production}) + 92.634\ (T) \qquad [4\text{-}13]$$

with R^2 = 75.76 percent.

The inclusion of the T term improves R^2 from 68.7

percent to 75.76 percent and reduces the mean square error by 19 percent. The positive sign in the time coefficient means that given that production is included in the model an additional increasing trend in constant dollar materials is present. This trend can be observed in Table A.4.

Electric Energy

$$\text{(Elec. Ener.)} = -14.02 + 0.002163\ \text{(Production)} + 7.644\ \text{(T)} \qquad [4\text{-}14]$$

with R^2 = 92.90 percent.

The T term improves the model by increasing R^2 from 85 percent to close to 93 percent and reducing mean square error by 50 percent. As in Equation [4-13], the positive T term coefficient indicates the presence of an increasing electric energy trend in constant dollars after production has been included in the model. This trend can be observed in Table A.4.

Capital

$$\text{(Fixed Capital)} = 4913.096 + 0.0036876\ \text{(Production)} + 1146.583\text{(T)} \qquad [4\text{-}15]$$

with R^2 = 99.47 percent. Similarly, as in Equations [4-13] and [4-14] the positive time term coefficient indicates an increase in constant dollar capital factor which is evident from Table A.4.

In this case small improvement is gained by using the two independent variables. However, this model is used in order to be consistent with the models developed for the other input factors.

Table A.4 shows the actual data and predictions from these models using the actual production data and the time period. Table 4.4 presents the actual data and the results that Equations [4-12] through [4-15] give by using the <u>forecasts of production</u> obtained from the ARIMA (2, 1, 2) process given in Equation [4-9] and the time period.

The results of these models are used to compute productivities. The productivities computed by predicting inputs with this approach are compared to the productivities obtained by using the constant value figures obtained from the time series models, and both methods are compared to the productivities obtained from the actual historical data.

Productivity Computations From Time Series Models of Inputs

The data to be used in these productivity computations is given entirely in Table 4.3. The output factor series are based on the forecasts of the time series model Equation [4-9] for production. This series is used in Equation [4-10] to predict shipments and revenues are predicted from Equation [4-11] using the shipments predictions.

The four input factors are given in constant 1967 value terms by adjusting time series models given in Equations [4-1] through [4-4] by the appropriate index series given in Equations [4-5] through [4-8].

Table 4.4. Input Factors: Actual and Predicted Data From Regression Models (Constant 1967 Values).*

	Labor		Materials		Electric Energy		Capital	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1950	7,857.36	7,399.87	5,584.23	4,280.06	221.52	150.87	6,713.15	6,327.68
1951	8,622.97	8,336.40	6,373.75	5,927.04	247.99	224.07	7,896.19	7,585.99
1952	7,780.08	8,272.06	6,422.35	6,158.13	233.03	237.56	9,436.03	8,742.49
1953	8,726.32	7,489.61	7,178.77	5,373.34	188.40	208.19	10,393.35	9,825.93
1954	7,363.64	8,052.76	5,385.76	6,492.12	239.38	259.12	10,946.06	11,046.25
1955	8,233.39	7,292.06	7,056.04	5,738.09	312.90	231.05	11,635.13	12,131.91
1956	8,184.06	8,148.83	7,710.13	7,272.25	321.84	299.50	12,939.60	13,382.10
1957	8,177.51	7,508.12	7,228.83	6,687.97	321.06	278.59	14,765.54	14,479.97
1958	6,492.82	7,403.91	5,603.31	6,862.66	237.79	289.70	15,883.81	15,632.40
1959	6,441.10	6,818.29	6,756.56	6,356.32	242.98	272.08	16,653.54	16,735.87
1960	6,893.77	6,948.98	6,307.45	6,863.31	271.97	297.20	18,064.77	17,912.20
1961	6,386.28	6,200.24	5,831.22	6,126.21	273.32	269.84	18,760.97	18,999.08
1962	6,278.12	5,862.94	6,464.77	5,971.15	279.89	267.04	19,274.47	20,127.80
1963	6,277.16	6,360.84	6,517.95	6,997.62	302.07	314.07	19,995.91	21,341.49
1964	6,706.12	6,851.13	7,382.98	8,013.33	349.07	360.65	21,411,46	22,554.40
1965	6,931.14	6,721.54	8,377.59	8,152.11	360.29	370.24	23,004.51	23,704.26
1966	6,993.12	6,330.95	8,166.09	7,921.67	376.30	364.26	24,670.50	24,827.57
1967	6,496.40	6,817.61	7,453.20	8,932.25	381.81	410.62	26,054.30	26,040.11
1968	6,654.16	6,974.40	8,377.56	9,476.16	414.57	437.30	28,006.89	27,219.10
1969	6,633.36	6,656.31	8,268.49	9,348.29	434.65	435.64	29,204.44	28,349.78
1970	6,425.40	6,135.22	8,328.09	8,933.23	445.31	421.87	30,580.87	29,459.81
1971	5,922.49	5,784.51	8,723.62	8,759.20	436.89	418.27	31,475.86	30,587.17
1972	6,070.91	6,028.30	9,064.97	9,426.19	463.04	450.14	32,112.50	31,775.01
1973	6,320.51	6,311.96	11,378.35	10,149.59	516.48	484.39	32,881.70	32,996.91
1974	6,215.15	5,834.37	12,939.08	9,796.07	509.64	473.21	33,477.17	34,081.36
1975	5,338.32	5,345.91	10,130.38	9,427.17	455.01	461.39	35,049.24	35,194.71
1976	5,381.77	5,288.82	10,546.35	9,668.52	487.71	475.31	36,574.69	36,351.94
1977		5,891.89		10,843.78		528.61		37,576.33
1978		5,297.31		10,324.76		510.46		38,678.88
1979		4,151.31		9,025.67		459.40		39,309.22
1980		4,357.44		9,639.37		489.02		40,909.35
1981		5,299.31		11,293.92		562.55		42,168.20
1982		4,850.45		10,981.05		553.08		43,285.58
1983		3,462.07		9,339.07		487.57		44,307.39
1984		3,485.48		9,694.30		506.29		45,472.81
1985		4,671.47		11,694.19		594.38		46,756.49
1986		4,445.60		11,696.77		598.22		47,896.55

*Millions of Dollars.

Similar productivity computations will be given for the actual historical data from 1950 to 1976 shown in Table 4.2.

Two sets of computations will be performed. One by dividing each output factor by the sum of the four inputs and other by dividing over three inputs, extracting the effect of capital. This is done because input factors such as labor, materials, and electric energy represent costs that are incurred during a given year. These costs are variable in nature. They will vary according to the level of output and can be viewed as the costs incurred at a particular period to provide that period's amount of output.

On the other hand, capital costs, measured as capital stock at a given period of time, is a fixed cost. Its level will not vary in the short run with increasing or decreasing amounts of output, as the other input factors do. This difference in the nature of the input factors suggests that the productivity trends should also be observed by extracting the effect of capital, leaving only the effect of the variable cost factors.

Table A.5 presents the productivity results for the four input factor case, using the time series forecasts for the input factors, along with similar computations performed by using the actual data. Table A.6 presents the results for the case of three inputs, excluding capital. Plots of these results are shown in Figure 4.11 through 4.14.

From Figures 4.11 and 4.12 we can make the following

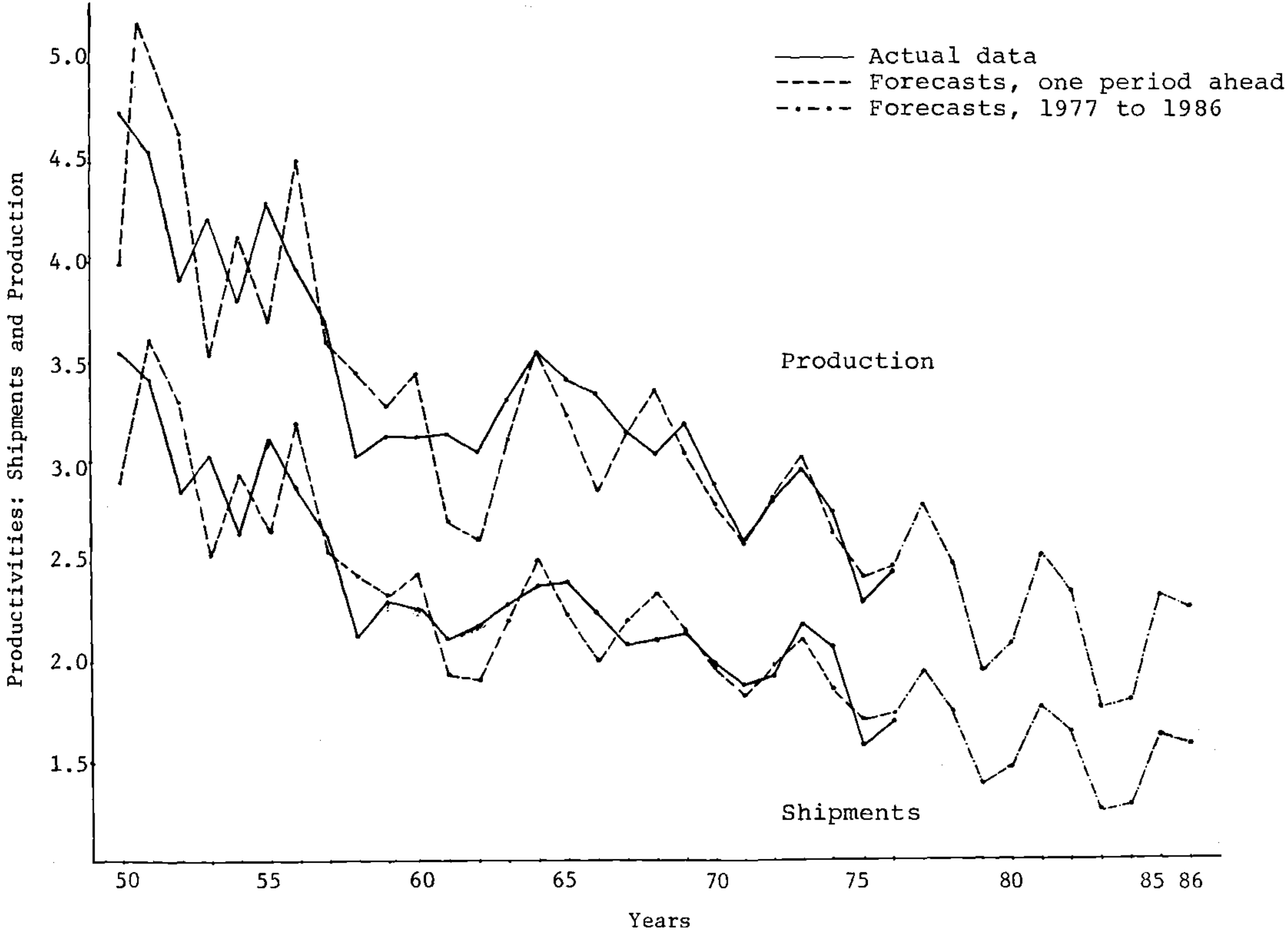

Figure 4.11. Productivities in Terms of Shipments and Production, Four Input Case (Inputs by Time Series).

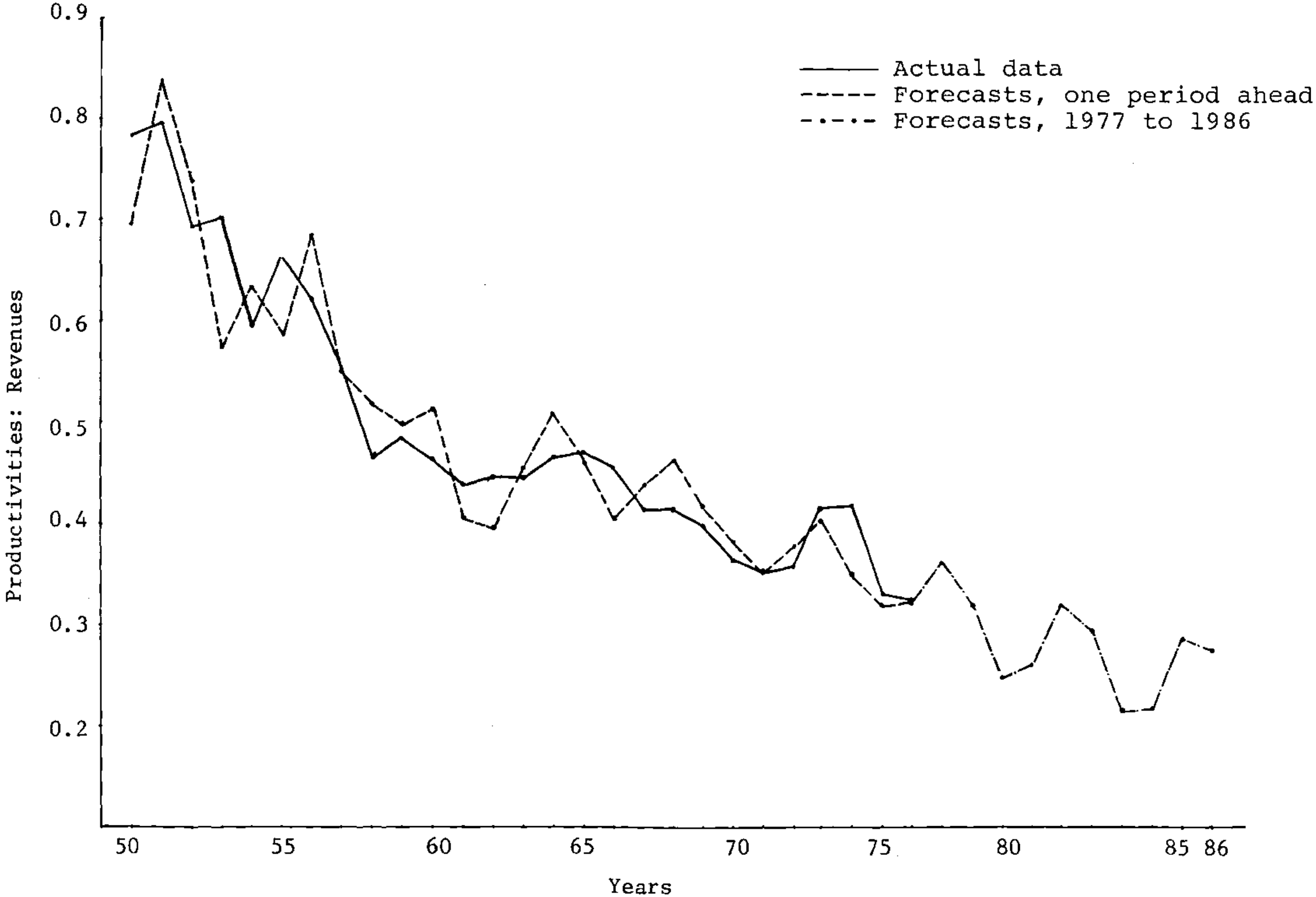

Figure 4.12. Productivities in Terms of Revenues, Four Input Case (Inputs by Time Series).

comments about productivities in respect to four input factors.

1. There is a decrease in productivity in both actual and forecasted data from 1950 to 1976. Declines of productivities are also forecasted from 1977 to 1986. Larger declines are observed until the late fifties and earlier sixties. Slight improvements occur during the earlier and mid-sixties but decreases continue from the late sixties and during the seventies but at a lower rate than in the sixties.
2. Shipments/L+M+EE+C: From 1950 to 1965 in most years a one period lag of the forecasted series respect to the actual series can be noticed. This is caused by the lag that exists during these years in the forecasted production series that is used to forecasts the level of shipments. From 1966 to 1976 the lag disappears and the forecasted series performs better in reproducing the actual variations. Despite the lags at earlier periods the modeled series is able to give a proper representation of the actual trend over the long run which is the main interest of this work.
3. Production/L+M+EE+C: There is a one period lag from 1950 to 1963. From 1964 to 1976 there is agreement on the increases and decreases of actual and forecasted series. The overall trend in the forecast series is a valid representation of the actual series.
4. Revenues/L+M+EE+C: Similar behavior as above is seen

but there are several early years when increases and decreases coincide, such as in 57-58, 58-59, 60-61, 62-63, and 63-64. After 1965 actual and modeled variations agree. There is also a valid representation of the actual trend with the model.

Figures 4.13 and 4.14 shows the trends considering only labor, materials, and electric energy input factors. The plots show different results from those of the four input factors. There are moderate increased from 1950 to the early sixties, then larger increases until the late sixties followed by decreases until 1976. This gives a representation of the trends of outputs in relation to the sum of variable costs input factors alone. The effect of the fixed cost capital stock factor is excluded. This has several implications. It can be seen that productivity gains have been achieved over some period of time if the effect of fixed capital stock is excluded. Also it can be observed that the forecasted series is now more volatile than the one that considers four inputs. The inclusion of capital had the effect of smoothing out year to year variations. These points will be treated further in later sections. From the individual plots it can be observed that:

1. Shipments/L+M+EE: From 1950 to 1959 there is a one period lag. From 1960 to 1976 increases and decreases coincide with those of actual data. The forecasted plot appears to be considerably more volatile than the

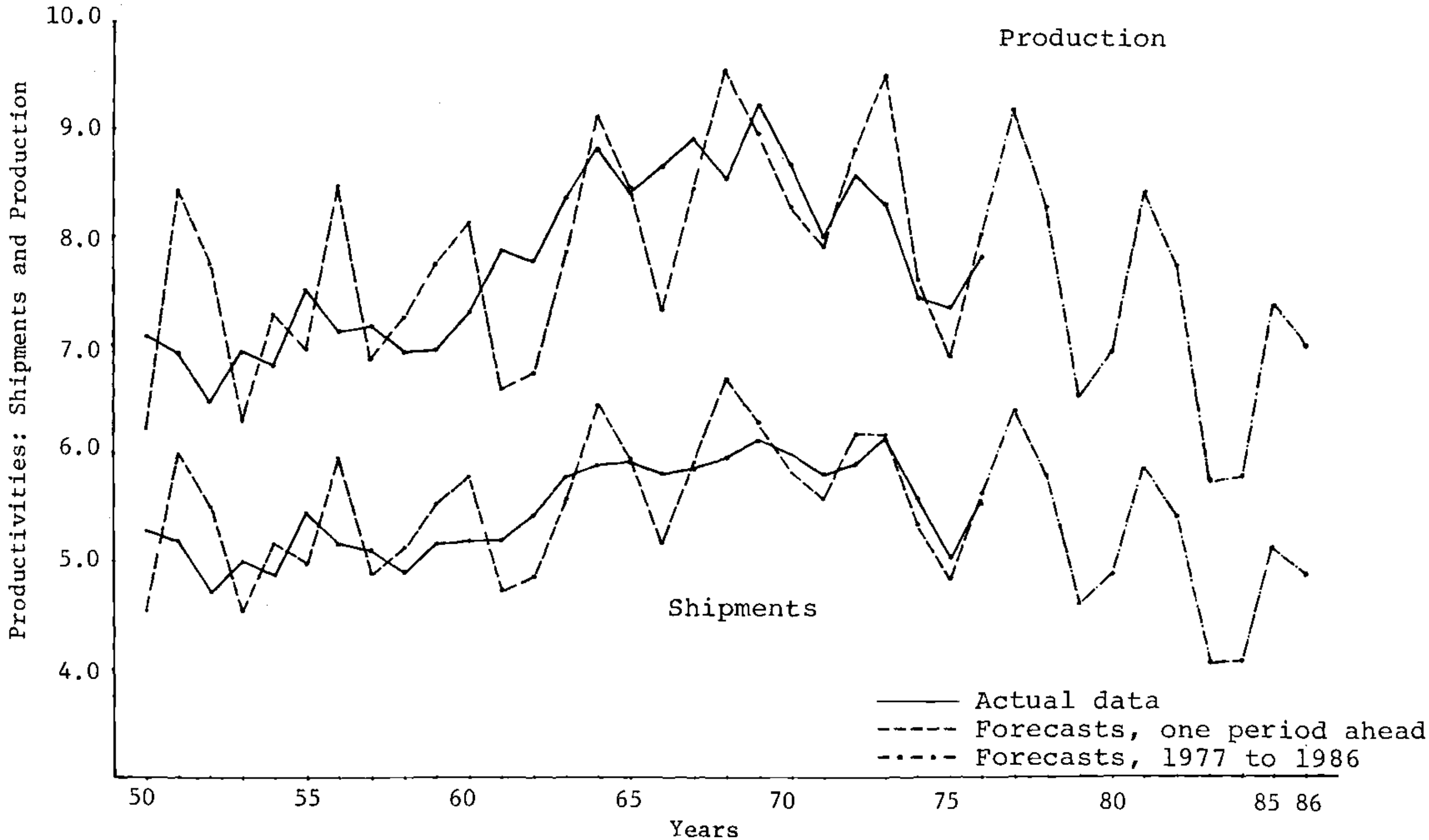

Figure 4.13. Productivities in Terms of Shipments and Production, Three Input Case (Inputs by Time Series).

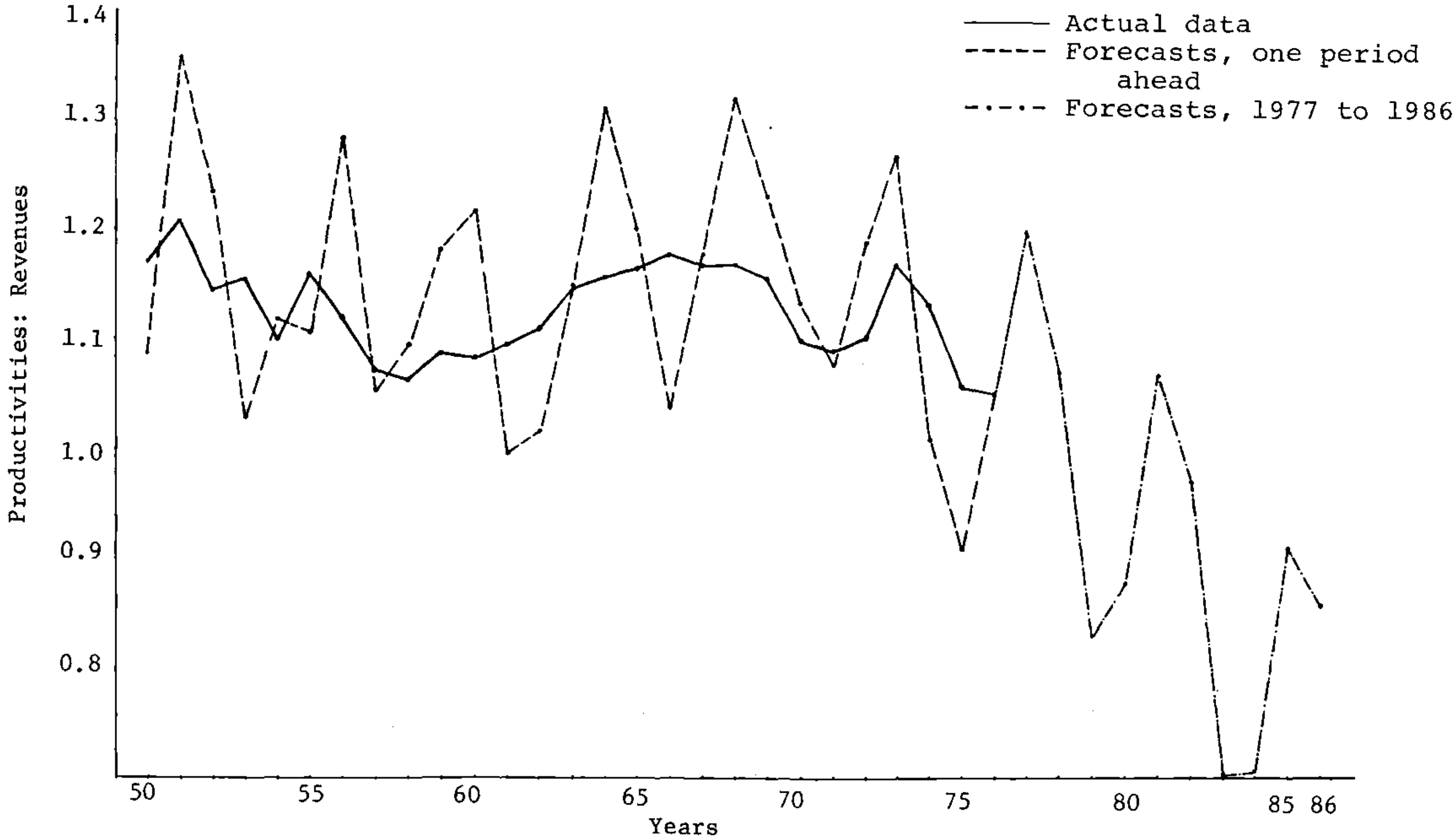

Figure 4.14. Productivities in Terms of Revenues, Three Input Case (Input by Time Series).

one for actual data.

2. Production/L+M+EE: A one period lag exists from 1950 to 1957. From 1963 to 1976 there is a mixed pattern but for most years increases and decreases in forecasted and actual series move together.

3. Revenues/L+M+EE: From 1950 to 1965 there are some years where there is agreement on increases and decreases and in others the one year lag is present. From 1965 to 1976, movements of both series go together. There is the exception between years 73 and 74. In this year, there was a larger than normal increase in steel prices that was not adequately predicted in the model, resulting in actual data increase when the model was predicting a large decrease.

Even though the three input models give representations of the actual data trends, it has the problem of the volatility, caused by the exclusion of capital from the denominator. Capital carried the largest share of input in the denominator and its variations were almost independent of the variations of the outputs. This resulted in a smoothing effect provided by capital. This explains the larger volatility in the productivity measures with three inputs than in the ones with the four inputs. But for both, still some variations can be explained by the fact that output factor of shipments and revenues are based on the forecasts for production. On the other hand, input figures used in the denominators vary according to their time series behavior and not respect to the forecasts of production as the output factors of the numerator do.

The next section presents results of actual and forecasted productivities by now using the regression relationships presented in the "Regression Models for Input Factors" section of this chapter, where each input factor is related to production and the time period. In this way both input and outputs will vary according to their relationship to a common factor.

Productivity Computations From Regression Models of Inputs

This section presents the results of productivities where the input factors are related to the forecasted production level and to the particular time period. These relationships have been presented earlier in Equations [4-12] through [4-15]. Outputs are forecasted as in the previous section. By using the one period ahead forecasts from Equation [4-9] into Equation [4-10] relating shipments to production and in turn using these shipment predictions in Equation [4-11] to predict revenues.

This approach makes use of the production forecasts to predict the level of both outputs and inputs. It represents a more consistent approach than the one presented in the previous section because it requires the forecasts of only one factor, from which input and output predictions can be obtained. Both the numerator and denominator of productivity are affected by the changing characteristics of the same factor. This facilitates the understanding of productivity changes. Tables A.7 and A.8 present these productivity results that can also be viewed in Figures 4.15 to 4.18.

The plots show that the volatility of the forecasted series has been reduced. This is more evident in the forecasted series based on only three inputs. The year to year increases and decreases are more moderate and resemble better the actual data variations.

It is also noted that the forecasted series generally lies below the actual series in time intervals when the actual series trend is increasing, and above it, when the actual series trend is decreasing. This behavior occurs because all the inputs and two outputs are predicted now by using regression expressions that tend to provide with a "best" straight line fit for those factors.

This makes the forecasted productivity series to be similar to a "best" straight line, that is being fitted to the actual productivity series.

The forecasts for the future ten year time span, 1977 to 1986, predict higher values than what is forecasted with the approach using time series models for the inputs. For the three input measures the forecasted series predicts increases at almost the same rate that was being predicted during the late sixties and seventies. The other approach

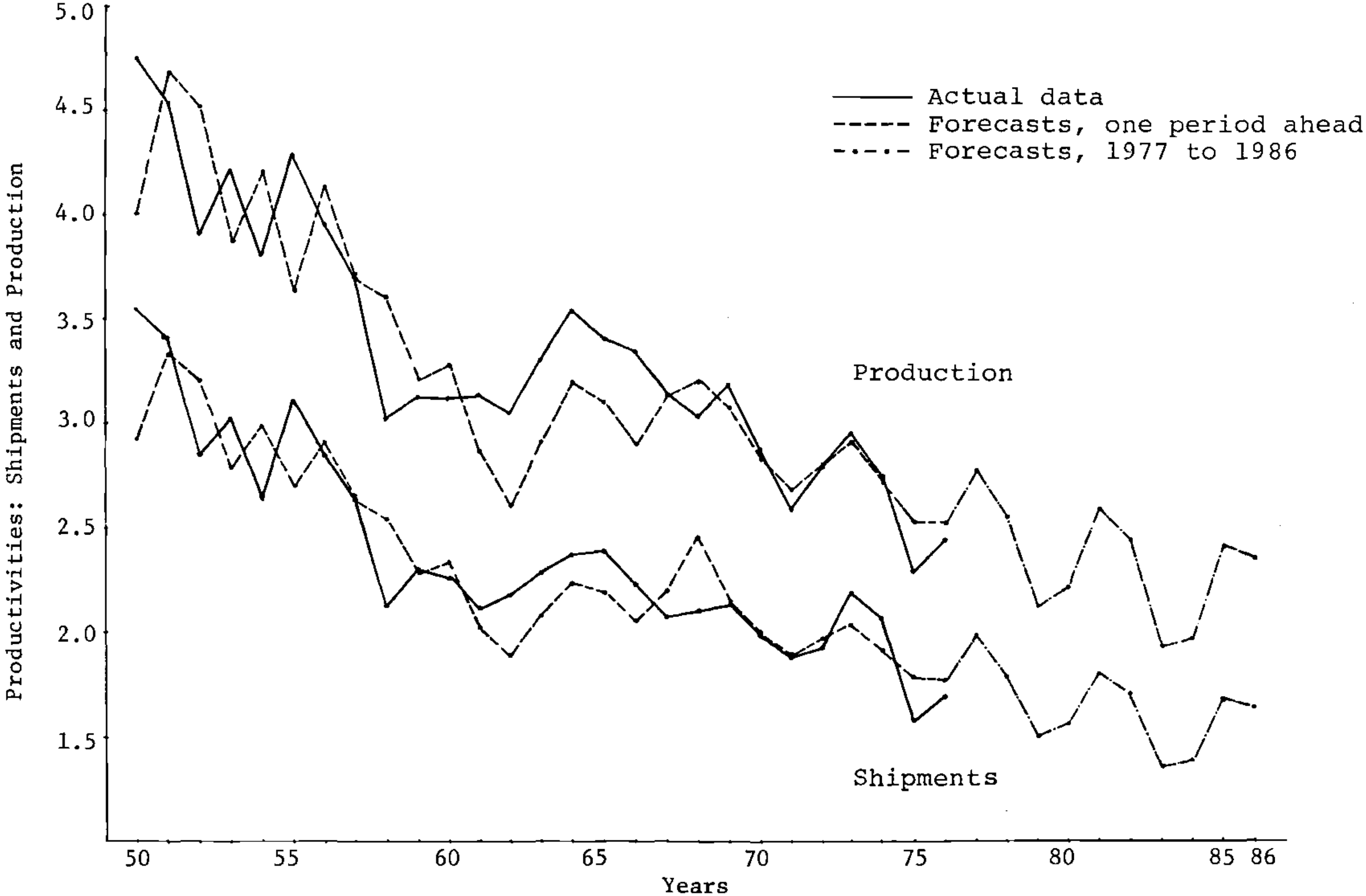

Figure 4.15. Productivities: in Terms of Shipments and Production, Four Input Case (Inputs by Regression).

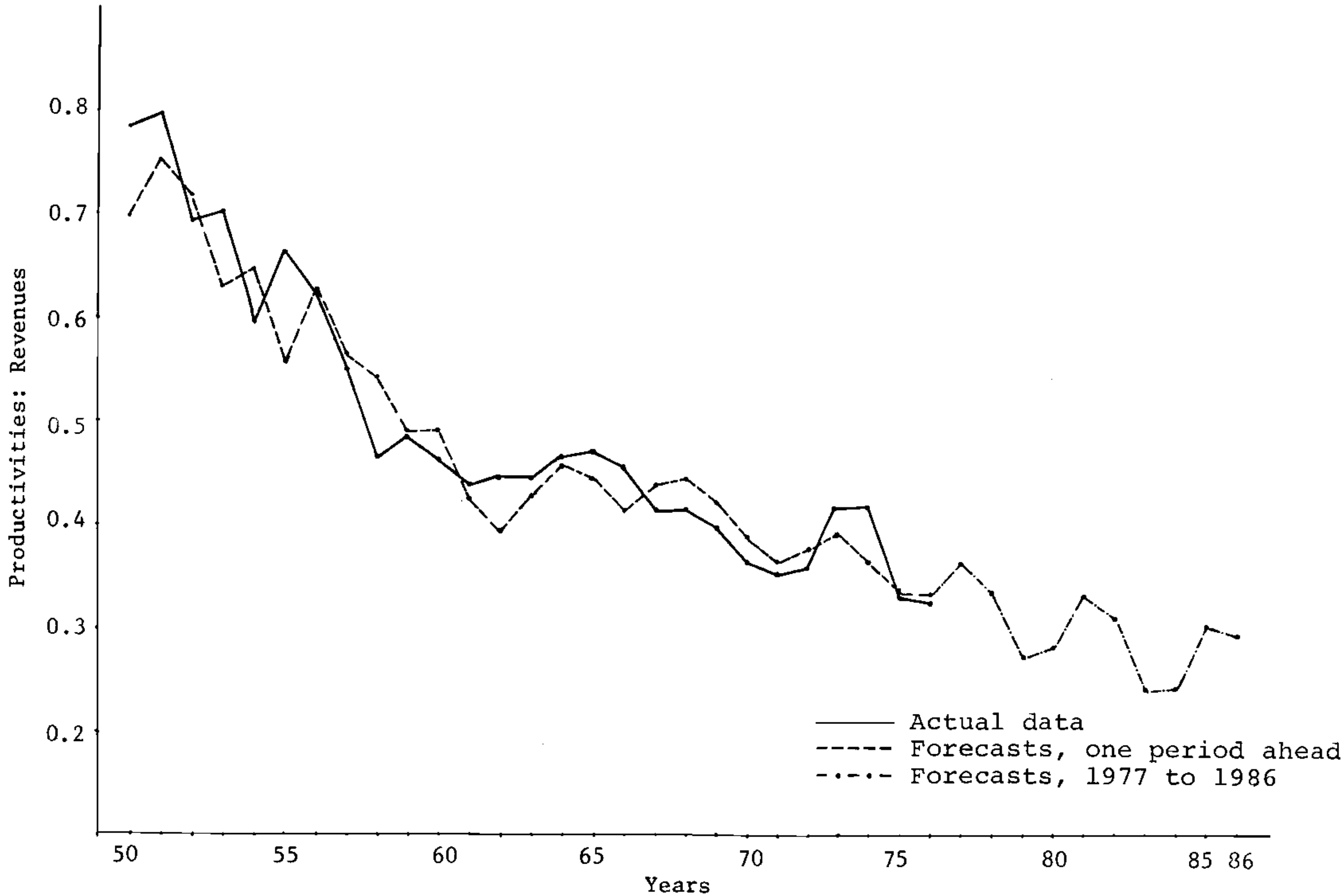

Figure 4.16. Productivities in Terms of Revenues, Four Input Case (Inputs by Regression).

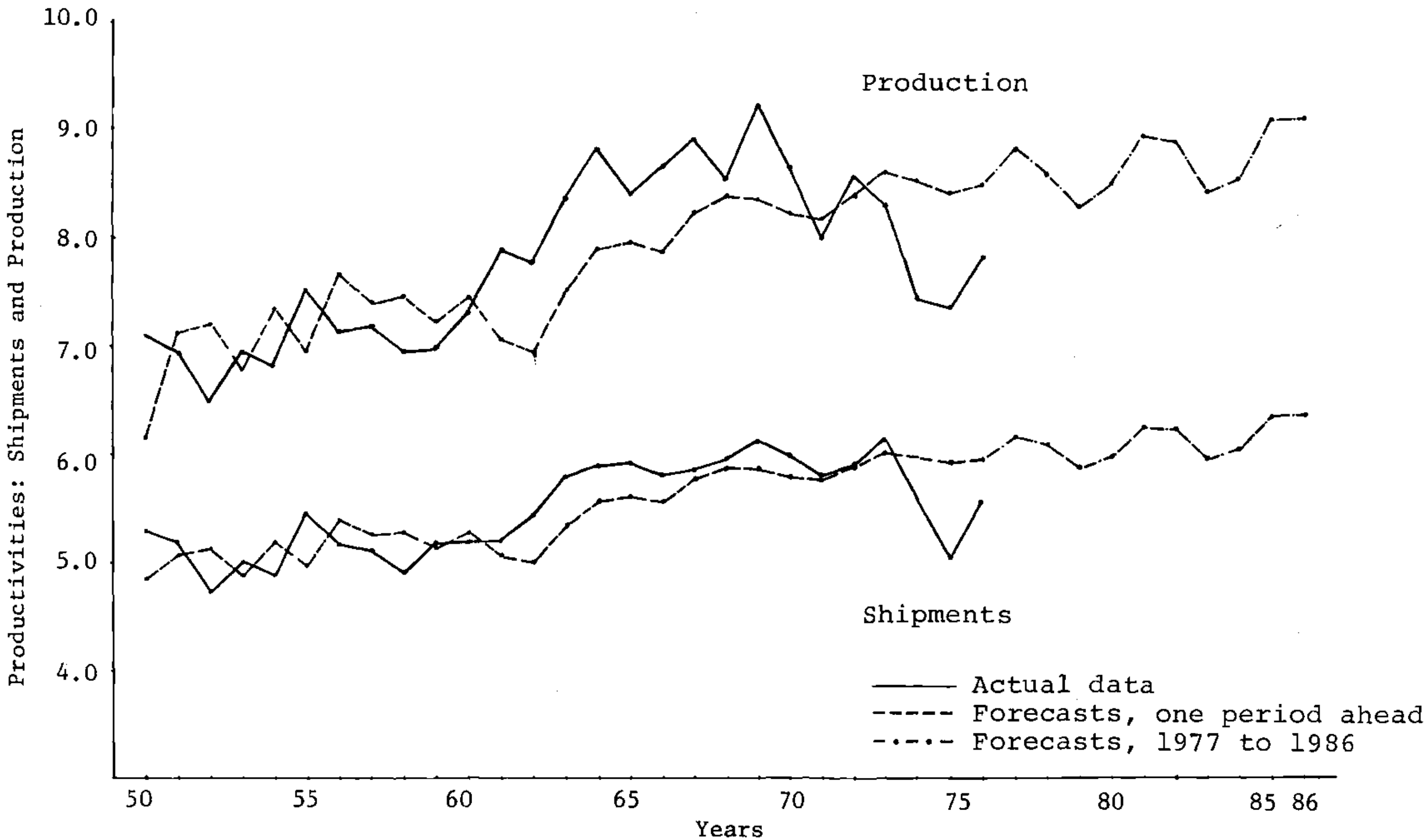

Figure 4.17. Productivities in Terms of Shipments and Production, Three Input Case (Inputs by Regression).

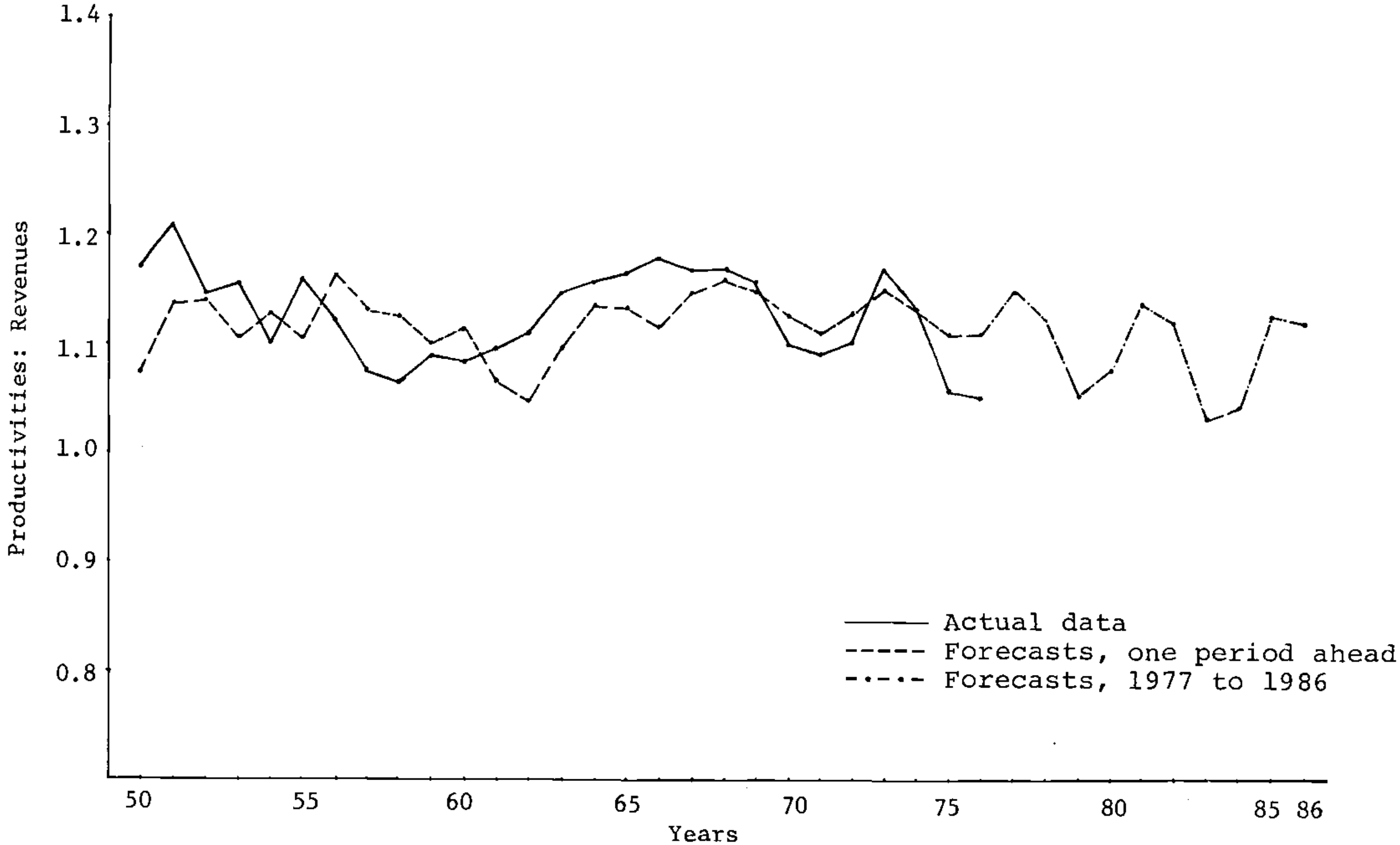

Figure 4.18. Productivities in Terms of Revenues, Three Input Case (Inputs by Regression).

forecasted steep variations with an overall decreasing trend. This downward trend was caused by the forecasted effect of the labor factor in constant value terms. From Table 4.3 it can be seen that the labor factor in constant value terms increases from 1978 to 1986 causing the forecasted productivity to have an overall downward trend. It is believed that the forecasted increase in constant dollar labor input is not justified because it would mean increasing the work force relative to the output and that contradicts the historical trend.

These results imply that the approach of relative input and output factors through regression expressions provide a more valid representation of the trends in actual data series and on what to expect in terms of the trends for future periods.

Rates of Change in Actual and Forecasted Productivity Series

Table 4.5 presents the results of Figures 4.15 through 4.18 in terms of the average annual percent change for each of the productivity series. The forecasted series are based in the regression models for the input factors.

The following observations can be made:

1. First both actual and forecasted series agree on decreasing trends when considering the four input case, and on small increased for the three input case.

Table 4.5. Productivity Measures Average Annual Percent Change*.

	Outputs Four Input Case			Outputs Three Input Case		
Time Interval	Shipments	Production	Revenues	Shipments	Production	Revenues
Actual 1950-1976	-2.27	-2.07	-2.05	+0.71	+0.83	-0.13
Forecasts 1950-1976	-2.08	-1.98	-2.93	+0.87	+0.97	+0.04
Forecasts 1977-1986	-1.64	-1.65	-2.36	+0.43	+0.45	-0.26

*Calculated by least squares of the series of indexes of productivity, 1967 = 100. This measurement approach is consistent with the method used by the B.L.S. to measure average annual rates of change in output per manhour indexes.

2. The forecasted rates of change show slightly smaller declines than the actual rates, for the case of four inputs and slightly larger gains than the actual for the case of three inputs.
3. The forecasted series from 1977 to 1986 show smaller declining rates than over the 1950-76 interval for the four input case. For the three input case, it shows smaller gains from 1977 to 1986 than what was forecasted from 1950 to 1976.
4. The revenues measure shows larger declines and smaller gains than the shipments and production measures.
5. For both the four input and three input cases, the forecasted rate of changes provide a good approximation of the actual rates of change.

In Table 4.6 the results of productivity average annual rate of changes in terms of production, are compared to the average annual rate of change of the ratio of production to the each individual input factor.

From Table 4.6 it is noted that the forecasted rates for the ratios of production to the individual input factors from 1950 to 1976 are very close to the actual rates. This results in similar productivities in terms of production for both forecasted and actual.

Decreasing rates in the capital, electric energy and

Table 4.6. Production Ratios Average Annual Rate of Changes (Percentages)

	1950-1976 Actual	1950-1976 Forecasted	1977-1986 Forecasted
Production/Labor	+2.94	+3.13	+3.47
Production/Materials	-0.84	-0.87	-0.77
Production/Electric Energy	-1.91	-1.96	-1.28
Production/Capital	-4.68	-4.56	-2.43
Production/Sum (4 inputs)	-2.07	-1.98	-1.65
Production/Sum (3 inputs) (Excluding Capital)	+0.83	+0.97	+0.45

materials ratio and increases in the labor ratio bring about decreasing rates of -1.98 percent per year for the four input case and increases of +0.97 percent per year for the three input case, that excludes the effect of capital.

It is evident that the larger declines in the production to capital stock ratio, drives productivity down, when the effect of capital is included. The larger declining rates for capital are added to the fact that capital, takes by far, the largest share as an input factor due to the capital intensive nature of the steel industry.

Forecasted production ratios for individual inputs from 1977 to 1986 show small overall improvements. Production in respect to labor shows higher gains and in respect to materials, electric energy and capital, it shows more moderate declines than from 1950 to 1976. This results in smaller declining rates of -1.65 percent for the four input case and slightly smaller gains of +0.45 percent for the three input case.

Sensitivity Analysis

It is the purpose of this section to observe what changes in average annual rates of productivity are obtained by varying the average annual rates of change for the forecasted input factors series.

This analysis will cover the forecasted ten year span from 1977 to 1986. It will give insight regarding what variations in productivity trends can result if the series of input factors vary at different rates from those that were forecasted by the models.

The analysis requires the following steps:

1. Computation of average annual rates of change from 1977 to 1986 for the input factors series obtained by using Equations [4-12] through [4-15]. These equations predict constant dollar value input factors in terms of the production forecasts and the time period.
2. Change each input factor's rate of change, from 1977 to 1986, obtained above, by a plus and minus one percent.
3. Compute a new series for each input factor's plus and minus one percent rate of change.
4. Compute productivity, having performed the plus and minus one percent change in the particular input series.

Eight changes are made, two for each of the four input factors.

This analysis is performed by making one change at a time with the other factors at their forecasted rates. For each input factor rate of change effected, a corresponding productivity rate of change results, that can be compared to the rates originally forecasted.

The productivity measure used is the ratio of production in respect to both the four and three input factors.

Table 4.7 presents the results of the analysis. The differences in average rates of change in productivity from those predicted by the models show the relative importance of each input factor in effecting productivity change.

For the four input case, the plus and minus one percent changes in capital result in ± 0.75 percent differences in the productivity rate. Whereas, materials and labor, effect smaller changes of ± 0.18 and ± 0.07 percent, respectively. It is noted that the largest improvement is obtained by reducing the capital input rate to -1.76 percent, the minus one percent change in capital. This changes the productivity rate from -1.65 percent to -0.89 percent. However, this change is still not large enough to produce a positive trend in productivity.

For the three input case, that excludes the effect of capital, it is noted that a ± 0.70 percent difference results from the materials change and approximately a ± 0.25

Table 4.7. Sensitivity Analysis Results.

	Production/Labor + Materials + Elec. Energy + Capital 1977-1986 Forecasted Average Annual Percent Rate Rate = -1.65%								Production/Labor + Materials + Elec. Energy 1977-1986 Forecasted Average Annual Percent Rate Rate = +0.45%					
Input Factors	Labor		Materials		Elec. Energy		Capital		Labor		Materials		Elec. Energy	
Input Factors Forecasted Rates (Percent)	-3.12		+1.09		+1.61		+2.76		-3.12		+1.09		+1.61	
Input Factors ± 1 Percent Change	-4.12	-2.12	+0.09	+2.09	+0.61	+2.61	+1.76	+3.76	-4.12	-2.12	+0.09	+2.09	+0.61	+2.61
Production/Σ Inputs Avg. Annual Rates (Percent)	-1.59	-1.73	-1.46	-1.82	-1.64	-1.66	-0.89	-2.39	+0.68	+0.17	+1.16	-0.24	+0.49	+0.41
Rate Difference From Forecasts	+0.06	-0.08	+0.19	-0.17	+0.01	-0.01	+0.76	-0.74	+0.23	-0.28	+0.71	-0.69	+0.04	-0.04

percent difference from the labor change. It is noted that the increase of one percent in the materials rate to +2.09 percent can reverse the positive +0.45 percent rate of productivity to a negative -0.24 percent rate.

The effect of the changes in electric energy, for both the four and three input cases are very small in relation to the effects of the changes of the other input factors.

In order to get a better understanding of the magnitude of the changes in the rates of input factors that are required to bring about productivity improvements, consider the results presented in Table 4.8. These show the improvements in average annual productivity rates of change when the forecasted labor series decreasing rate is made twice as large and the increasing capital, materials and electric energy rates are reduced by half. The magnitude of these changes will be different for each input factor and will be proportional to each input series forecasted rate of change.

For the four input case none of the changes in the input rates are large enough to reverse the negative productivity trends. This means that when changes are effected one at a time, larger improvements in the rates of change in input series are required to produce positive trends in the ratio of production in respect to the sum of the four inputs.

Capacity Expansion Hypothesis

The last part of Chapter II covered the forecasts and outlooks that several steel industry analysts have made about

Table 4.8. Productivity Improvements.

	Production/Labor + Materials + Elec. Energy + Capital 1977-1986 Forecasted Ave. Annual Rate = -1.65%				Production/Labor + Materials + Elec. Energy 1977-1986 Forecasted Ave. Annual Rate = +0.45%		
Input Factors	Labor	Materials	Elec. Energy	Capital	Labor	Materials	Elec. Energy
Input Factors Forecasted Rates (Percent)	-3.12	+1.09	+1.61	+2.76	-3.12	+1.09	-1.61
Input Factors Half and Twice Rates Improvements	-6.240	+0.545	+0.805	+1.380	-6.240	+0.545	+0.805
Production/Σ Inputs Ave. Annual Rates (Percent)	-0.85	-1.60	-1.64	-0.62	+1.14	+0.85	+0.47

future demand prospects and on what effect this may have on the need for increasing new capacity and replacing the obsolete existing equipment. So it is possible to hypothesize a schedule of increases in production capacity resulting from additional expenditures that are expected in order to increase such capacity. Thinking in terms of a productivity framework, this means increases in the production output factor and in the fixed capital stock input factor. However, the other two output and three input factors should be modified in order to take into account the increased production levels. This is done by using the relationships [4-10] and [4-11] for outputs and [4-12] through [4-15] for inputs, that relate each of these factors to production. Doing this, the new forecasted series for production and capital stock are assumed based on what the industry expects to do in terms of capacity expansion. Then the remaining factors are obtained by using the previously developed relationships.

It will then be possible to compare the previously developed productivity trends for the future, with the ones that will result due to this particular program of capacity expansion predicted by the industry. It should be clear that the previously forecasted trends of productivity assume in their forecasts from 1977 to 1986, that the historical relationships between outputs and inputs will continue. The capacity expansion hypothesis developed here is explicitly assuming a different capital factor relationship from the one predicted from historical data. The same is true for the production factor. One purpose is to observe how these changes reflect in the productivity series.

From the opinions of the analysts mentioned in Chapter II[44,48,55,58] certain capacity expansion assumptions are made. It is assumed that an approximate 15 percent of capacity increases has been postponed after the 1975 recession.[44] This means that Dilley's[55] original estimate of 25-23 million tons of additional capacity by 1980 can be reduced to 20 million tons, and that the estimated capital expenditure requirements of $4.5-5.0 billion per year can be reduced to an approximate $4.0 billion per year.

An estimated schedule of capital expenditures and increases of capacity requires other assumptions. Due to the delays and deferred expansions due to the 1975 recession and to the well publicized capital shortage, the time span during which the capacity expansion is to be accomplished will be the six year span from 1977 to 1982 instead of the period between 1975 and 1980 originally assumed by the authors in late 1974. It is then assumed that an average one year lag for capacity to become fully productive exists and an average of 90 percent capacity utilization during the six year time span will result. The assumed schedule of capital expenditures and production is given in Table 4.9. The production schedule shown in the right hand column of Table 4.9 also agrees with the latest forecasts given by the

Table 4.9. Capacity Expansion Schedule Assumed.

Year	Capital Expenditure (Billion Dollars)	Additional New Capacity (Million Tons)(1)	Estimated Available Production Capacity (Million Tons)	Production 90 Percent Capacity Utilization (Million Tons)	Production 90 Percent Capacity One Year Lag (Million Ton)
1977	$4.0	3.33	162.33(2)	146.1	143.1
1978	4.0	3.33	165.67	149.0	146.1
1979	4.0	3.33	169.00	152.1	149.1
1980	4.0	3.33	172.33	155.1	152.1
1981	4.0	3.33	175.67	158.1	155.1
1982	4.0	3.33	179.00	161.1	158.1
1983	4.0(3)				161.1

(1) 20 Million tons/6 yrs. = 3.33 tons/year.
(2) Based on production capacity of 159 million tons by 1976 (from AISI).
(3) Assumed in order to be able to compute productivity in 1983 because increase in production extends to 1983 due to the assumed one year lag.

Table 4.10. Capacity Expansion Data

Year	Labor (Millions of Dollars)	Materials (Millions of Dollars)	Electric Energy (Millions of Dollars)	Capital (Millions of Dollars)	Production (Thousands of Tons)
1977	5,572.48	10,391.92	509.56	38,772.49	143,100
1978	5,519.02	10,638.40	523.69	40,970.29	146,100
1979	5,465.55	10,884.88	537.82	43,168.09	149,100
1980	5,412.09	11,131.36	551.96	45,365.89	152,100
1981	5,358.63	11,377.84	566.09	47,563.69	155,100
1982	5,305.16	11,624.32	580.22	49,761.49	158,100
1983	5,257.70	11,870.79	594.36	51,959.29	161,100

U. S. Industrial Outlook[58] that predicts shipments of 107 million tons by 1982. Roughly shipments represent 68 to 70 percent of production. From our schedule, this means 158.1 x 0.68 = 106.5 million tons by 1982 which agrees with the U. S. Industrial Outlook Forecast.

Table 4.10 shows the data used in the computation of productivities for the assumed capacity expansion schedule.

Productivity results in terms of the ratio of production to the sum of the four or the sum of the three inputs, exluding capital, are presented in Table 4.9.

Table 4.11 shows that the ratio of production to the sum of labor, materials, electric energy, and capital inputs decreases at an average annual rate of -1.93 percent. The

Table 4.11. Capacity Expansion Average Annual Rates of Change (Percent)

	$\frac{\text{Production}}{\text{L+M+EE+C}}$	$\frac{\text{Production}}{\text{L+M+EE}}$
Capacity Expansion (1977-1983)	-1.93	+0.76
Forecasted (1977-1986)	-1.65	+0.45

ratio of production to the sum of the three inputs, exluding capital, increases at an average annual rate of +0.76 percent. Comparing these rates with the ones forecasted from 1977 to 1986, based on the historical relationships of the previous section, we notice that production in respect to the four inputs decreases from an average -1.65 percent per year to an average -1.93 percent per year. On the other hand, the ratio of production to the sum of the three inputs, excluding capital, increases from an average annual rate of +0.45 percent to +0.76 average percent per year. This means that the assumed rate of capital expenditures required to increase production capacity not only fails to increase productivity, but it results in even larger declining rates. This occurs because the increases in production are more than offset by the increases in capital stock.

If the effect of capital is excluded, it is noted that improvements in productivity occur. This means that production is increasing at a larger rate than the sum of the other three input factors.

Obviously, these results and interpretations are based on our assumptions, which can be summarized as follows:

1. 20 million tons of additional capacity from 1977 to 1982. Capital expenditures of $4.0 billion per year, accounting for inflation, over this six year time span, that includes expenditures for added capacity, replacements and pollution control required by the government. This takes into account an approximate 15 percent reduction in capacity expansion programs from what was originally planned in 1975. These figures assume an approximate 13 percent share of shipments accounted by imports.
2. Schedule of capital expenditures and capacity increases assumes a one year lag.

3. 90 percent average capacity utilization from 1977 to 1983.
4. Assume that an insignificant amount of existing facilities will be scrapped. It assumes that the replaced equipment and machinery will be used on stand-by basis in order to be able to meet peak demands. From the available data it is difficult to come up with a scrappage rate based on historical data.
5. Assume a $4.0 billion expenditure in 1983 in order to take into account the increased capacity in that year, resulting from the expenditure in 1982.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study has measured composite productivity for the aggregate U. S. iron and steel industry, by taking annual shipments, production and revenues as output factors in relation to labor, materials, electric energy and capital input factors in constant value terms. Two cases for treating inputs are considered. In relation to the four input factors mentioned above and also in relation to labor, materials, and electric energy, omitting the effect of capital. Comparison of these two cases provide conclusions about the effect of the industry's capital stock in respect to productivity.

A model to be used in productivity calculations is developed. Model equations for output and input factors are obtained by using forecasting and regression techniques. Input factors are modeled by both, time series and regression approaches. The time series approach uses actual data for input factors in absolute value terms to obtain model parameters. These absolute value series are deflated by appropriate index series which are also modeled by time series in order to obtain the constant dollar value of inputs. The regression approach relates the annual production level and the given time period to the constant value of the various input factors. Outputs are modeled by using time series forecasts of production in a regression model relating shipments to production. Revenues is then predicted by relating it to the level of shipments and the particular time period.

Productivity measurements from 1950 to 1976 is performed for the actual data. The actual data results are compared to those obtained by the models, using the one period ahead forecasts from 1950 to 1976. The ten year period forecasts from 1977 to 1986 are obtained from the models.

The productivity results based on the regression models that relate input factors to the production level and the time period, provide better results than the approach that uses time series to model the input factors. The regression approach is more consistent in treating outputs and inputs. It predicts both outputs and inputs from each year's forecasted level of production and time period. On the other hand, the time series approach treats outputs by its relation to production also, but treats inputs by only taking into account their timely behavior, and not explicitly relating them to the level of output for a particular year. This can result in large year to year variations in productivity. Treating inputs with the regression approach reduces this large variability or volatility in the forecasted productivity, making them more representative of the actual data variations.

Productivity average annual rates of change from 1950 to 1976 are calculated for both the actual and forecasted data from the regression approach. Forecasted average rates of change are obtained from 1977 to 1986.

Sensitivity analysis is performed by assuming different rates of change in the input factors from those forecasted by the models, and observing what effects do they have in the productivity trends. The forecasted input factors rates of change from 1977 to 1986 are changed by ± one percent and the effect of these changes are measured in terms of the new productivity rates of change obtained.

A capacity expansion program is hypothesized from 1977 to 1982, and its effect on productivity rates is measured. It is based on estimates that have been presented by several steel industry analysts of the estimated capital expenditure requirements to increase capacity, make replacements and meet pollution control standards. In addition other simplifying assumptions are included.

The conclusions of this study are appropriate in terms of the assumptions made and the measurement and methodology procedures utilized in treating output and input factors. The overall conclusions can be summarized in the following points:

1. Negative productivity rates are obtained by measuring each of the three outputs in respect to the sum of the

four inputs. These rates show productivity declines between two and three percent per year. Measuring outputs in respect to the sum of labor, materials, and electric energy, explicitly omitting the effect of capital give result to positive productivity rates ranging from close to zero growth to slightly below one percent per year. These results indicate that the increased in capital stock over the years, have brought about smaller than proportional increases in output factors. The constant dollar capital increases have given continuing decrease in composite productivity. When the effect of capital is excluded it is noticed that some composite productivity improvements have been achieved.

2. Composite productivity forecasts from 1977 to 1986, show that if the observed rates of change in output and input factors continue in the future, only small improvements in the negative rates of change for composite productivity in terms of the four inputs, are likely to occur.
3. Sensitivity analysis has shown the relative importance of each input factor in bringing about composite productivity changes. The capital intensive nature of the steel industry makes capital the most important input factor in effecting productivity changes. A ± one percent variation from the forecasted rate of growth of capital stock causes a ±0.75 percent variation in the forecasted ratio of production to the sum of the four

inputs. The analysis has shown that even if the forecasted rate of growth in capital, materials, and electric energy is cut by half and the declines in labor's rate doubled, positive productivity rates are not obtained yet, when each of these changes is brought in one at a time, leaving the other factors at their forecasted rates.

4. The capacity expansion program hypothesized from 1977 to 1982 fails to show improvements in the rates of change of composite productivity in respect to the four inputs. The estimated capital expenditures required for adding new capacity, making replacements, and meeting pollution control standards, are too large to improve future composite productivity rates of change. Rates from 1977 to 1983, for the capacity expansion program assumed, show larger decreases of -1.93 percent per year compared to -1.65 percent per year forecasted from 1977 to 1986.

5. The results of this study show how different the results of a partial productivity measure, such as the commonly used output per manhour, published by the B.L.S., can be in relation to the results obtained by using productivity measures that explicitly take into account the effect of various important input factors. The average annual rates of change of the B.L.S. index of output per employee hour for the steel industry show a 1.7 percent increase from 1950 to 1976 and a more moderate growth of 1.3 percent from 1971 to 1976. The explicit consideration of the

effects of additional input factors shows that improvements in labor productivity are not large enough to provide positive composite productivity trends, where other input factors, including capital are considered.

Recommendations

It has been shown in this study that the measurement of composite productivity that considers several input factors, gives a more comprehensive view of productivity than partial productivity measures that only consider one input factor. The study has provided an approach to be used in forecasting and predicting annual level of output and inputs factors from which productivity predictions can be computed. This requires a specific measurement approach to obtain each output and input factor. Further research in this area should emphasize the measurement process, because it is critical in the success of a particular productivity measure. The improvement of a measurement system for dealing with aggregate data can be very complicated and might require tedious adjustments. Despite this fact, it is appropriate to make attempts to disaggregate each factor's contribution into homogeneous components. For example, labor input might consider separately the different workers skills. Materials can be separated by major raw material types. Energy input should include all energy sources separately. Similarly, the different plant equipment, machinery and processes can separately be taken into account. The same is true for the output factors, where classification might be done in terms of the different steel products.

Disaggregation, in addition to providing a more precise measurement procedure, would permit a better understanding of the variations that might result through time in the individual output and input factors.

Other recommendations dealing with the measurement procedure and other areas are given in the following points:

1. Improvement of the measurement approach can be gained if some adjustment in output and input factors are performed to assure that input levels represent the resources used to provide with the reported level of output for a particular year. An example of this would be an adjustment for inventories, for units of output produced and sold in different years, etc.
2. Disaggregating output and input factors data, as it is mentioned above, might permit one to compute physical unit quantities to be multiplied by appropriate unit costs or unit prices. This would permit the use of less aggregated indexes as deflators of the absolute value data.
3. An attempt should be made to measure the capital input by alternative approaches, other than gross capital stock. The approaches mentioned in the literature of applying a base period rate of return and the lease value concepts can be used to compute each year's contribution of capital.

4. Having calculated the capital input by alternative approaches, an attempt should be made to compute cost of additional capacity needed in order to produce composite productivity increases. This would give insights on the possibilities or not of improving composite productivity through the installation of new capacity.
5. An attempt should be made to obtain forecasts or predictions of the output factors by taking into account the expected demands of the major market sectors. An example of this is shown in Appendix II of this study but in order to be of use it would require a formal approach for obtaining forecasts of the demands of the more significant market sectors.

APPENDIX I

Table A.1. Input Factors: Actual Data and Forecasts From Time Series Models (Absolute Value).*

	Labor		Materials		Electric Energy		Capital	
Year	Actual	Forecasts	Actual	Forecasts	Actual	Forecasts	Actual	Forecasts
1950	3,100	2,812	4,400	3,723	249	210.4	8,100	7,899
1951	3,800	2,987	5,500	4,278	274	202.2	9,100	8,699
1952	3,700	3,795	5,400	5,609	261	250.8	10,400	10,100
1953	4,400	3,806	6,100	5,418	307	261.0	11,200	11,700
1954	3,800	4,299	4,600	6,185	263	280.4	11,700	12,000
1955	4,700	4,070	6,100	4,663	318	287.0	12,300	12,200
1956	5,000	4,511	7,000	6,166	320	289.0	13,400	12,900
1957	5,500	5,146	6,700	7,133	328	332.1	15,100	14,500
1958	4,700	5,455	5,200	6,842	250	339.3	16,200	16,800
1959	5,100	5,032	6,400	5,340	254	295.8	17,000	17,300
1960	5,500	5,052	6,000	6,544	292	239.3	18,300	17,800
1961	5,300	5,652	5,500	6,203	296	266.2	19,000	19,600
1962	5,400	5,512	6,100	5,692	299	297.5	19,500	19,700
1963	5,600	5,572	6,200	6,334	311	302.6	20,100	20,000
1964	6,100	5,821	7,000	6,478	354	312.8	21,500	20,700
1965	6,500	6,290	8,100	7,324	360	349.9	23,000	22,900
1966	6,800	6,781	8,000	8,503	372	387.3	24,700	24,500
1967	6,400	7,130	7,600	8,473	381	400.8	26,100	26,400
1968	7,000	6,946	8,600	8,124	415	417.1	28,100	27,500
1969	7,400	7,359	8,800	9,208	438	447.5	29,300	30,100
1970	7,600	8,008	9,200	9,520	469	490.2	30,800	30,500
1971	7,700	8,280	9,900	10,020	502	530.2	31,900	32,300
1972	8,700	8,550	10,700	10,860	564	578.2	32,600	33,000
1973	10,200	9,496	14,500	11,810	677	646.9	33,600	33,300
1974	11,800	11,140	19,900	15,830	881	771.5	34,500	34,600
1975	11,800	12,900	17,400	21,560	971	994.9	37,100	35,400
1976	13,200	13,460	19,200	19,340	1,190	1,217.0	39,900	39,700
1977		14,701		21,337		1,438.1		42,695
1978		16,686		23,898		1,779.1		45,485
1979		18,845		26,847		2,206.2		48,271
1980		21,468		30,310		2,764.9		51,052
1981		24,458		34,337		3,480.9		53,828
1982		27,992		39,043		4,407.3		56,599
1983		32,083		44,529		5,600.7		59,365
1984		36,877		50,932		7,141.2		62,126
1985		42,455		58,401		9,127.8		64,883
1986		48,970		67,162		11,690.7		67,635

*Actual data rounded off.

*Millions of dollars.

Table A.2. Indexes: Actual Data and Forecasts From Time Series Models.

	Steel Price Index		Labor Index		Industrial Commodities Index		Electric Energy Index	
Year	Actual	Forecasts	Actual	Forecasts	Actual	Forecasts	Actual	Forecasts
1950	59.40	60.41			78.00	76.07	113.0	121.5
1951	64.00	62.86	44.40	42.12	85.10	78.90	111.0	112.7
1952	65.40	68.53	48.70	49.11	84.10	89.30	112.0	115.1
1953	70.50	67.85	51.30	52.34	84.80	81.81	110.0	115.5
1954	73.80	76.07	52.80	54.60	85.00	87.50	110.0	111.5
1955	77.20	76.61	57.20	55.25	86.90	84.15	102.0	114.4
1956	83.80	81.63	62.10	62.39	90.80	89.36	99.5	96.9
1957	91.80	88.78	67.60	66.57	93.30	91.99	102.0	104.5
1958	95.00	96.22	73.80	73.25	93.60	95.09	105.0	104.1
1959	96.50	96.43	79.80	79.06	95.30	94.35	105.0	110.3
1960	96.40	98.47	80.30	85.20	95.30	97.61	108.0	106.0
1961	96.00	97.53	83.80	81.52	94.80	96.15	108.0	115.0
1962	95.80	97.99	87.30	89.03	94.80	96.78	106.0	108.9
1963	96.30	98.18	89.30	90.68	94.70	96.54	103.0	109.4
1964	97.10	99.63	91.50	9.355	95.20	96.97	102.0	103.3
1965	97.50	100.9	94.10	95.35	96.40	97.81	100.0	105.8
1966	98.90	101.9	97.40	99.54	97.40	99.60	99.0	100.3
1967	100.0	104.8	100.0	103.2	100.0	100.7	100.0	102.3
1968	103.0	106.4	106.0	106.5	103.0	104.6	100.0	102.9
1969	107.0	111.7	113.0	115.7	106.0	107.7	101.0	102.6
1970	114.0	116.6	119.0	123.6	110.0	111.6	105.0	104.9
1971	123.0	126.1	132.0	130.2	114.0	116.5	115.0	111.3
1972	130.0	135.9	149.0	149.2	118.0	121.2	122.0	126.5
1973	134.0	142.7	161.0	168.1	127.0	126.2	131.0	129.7
1974	170.0	147.5	191.0	177.8	154.0	138.2	173.0	145.3
1975	197.0	198.8	223.0	222.1	172.0	172.6	214.0	216.7
1976	210.0	209.0	247.0	249.9	182.0	184.6	244.0	247.2
1977		221.2		271.4		198.4		285.3
1978		231.3		294.9		218.0		340.3
1979		241.0		318.5		240.3		410.4
1980		250.4		341.8		266.2		500.0
1981		259.5		365.0		296.0		614.3
1982		268.3		388.0		330.5		760.1
1983		276.8		411.0		370.3		946.3
1984		285.2		433.9		416.2		1,183.8
1985		293.2		456.8		469.1		1,487.0
1986		301.1		479.6		530.2		1,873.8

Table A.3. Production Actual* and Forecasts (Millions of Tons).

Year	Actual	Forecasts
1950	96.800	72.690
1951	105.000	103.000
1952	93.100	105.700
1953	112.000	88.590
1954	88.300	108.600
1955	117.000	92.090
1956	115.000	120.200
1957	113.000	107.000
1958	85.200	108.600
1959	93.400	96.920
1960	98.200	105.000
1961	98.000	88.820
1962	98.300	83.990
1963	109.000	102.200
1964	127.000	120.200
1965	131.000	121.100
1966	134.000	114.800
1967	127.000	132.700
1968	131.000	141.500
1969	141.000	137.200
1970	132.000	127.300
1971	120.000	122.100
1972	133.000	133.300
1973	151.000	145.600
1974	146.000	136.900
1975	117.000	127.900
1976	128.000	130.800
1977		151.911
1978		139.984
1979		112.845
1980		123.006
1981		153.464
1982		145.556
1983		111.731
1984		116.852
1985		154.043
1986		152.287

*Actual data rounded off.

Table A.4. Input Factors: Actual Data and Predictions From Regression Models (Constant 1967 Value).*

	Labor		Materials		Electric Energy		Capital	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1950	7,857.36	8,275.52	5,584.23	5,518.31	221.52	203.09	6,713.15	6,416.72
1951	8,622.97	8,416.53	6,373.75	6,039.86	247.99	228.82	7,896.19	7,594.10
1952	7,780.08	7,818.12	6,422.35	5,515.47	233.03	210.44	9,436.03	8,696.27
1953	8,726.32	8,324.49	7,178.77	6,553.85	188.40	257.98	10,393.40	9,910.82
1954	7,363.64	7,317.64	5,385.76	5,451.78	239.38	215.23	10,946.10	10,971.44
1955	8,233.39	8,196.78	7,056.04	7,017.37	312.90	285.00	11,635.10	12,223.90
1956	8,184.06	7,968.59	7,710.13	7,016.67	321.84	288.71	12,939.60	13,363.73
1957	8,177.51	7,715.70	7,228.83	6,981.05	321.06	290.94	14,765.50	14,501.04
1958	6,492.82	6,557.96	5,603.31	5,665.49	237.79	239.19	15,883.80	15,546.32
1959	6,441.10	6,692.70	6,756.56	6,178.17	242.98	264.55	16,653.50	16,723.06
1960	6,893.77	6,705.81	6,307.45	6,518.80	271.97	282.66	18,064.80	17,887.43
1961	6,386.28	6,533.88	5,831.22	6,597.69	273.32	289.72	18,761.00	19,032.98
1962	6,278.12	6,383.05	6,464.77	6,706.43	279.89	298.05	19,274.50	20,180.67
1963	6,277.16	6,617.20	6,517.95	7,359.73	302.07	329.34	19,995.90	21,367.53
1964	6,706.12	7,100.85	7,382.98	8,365.95	349.07	375.51	21,411.50	22,579.76
1965	6,931.14	7,097.64	8,377.59	8,683.50	360.29	392.64	23,004.50	23,742.47
1966	6,993.12	7,031.10	8,166.09	8,911.47	376.30	406.00	24,670.50	24,898.74
1967	6,496.40	6,619.18	7,453.20	8,650.88	381.81	398.74	26,054.30	26,019.88
1968	6,654.16	6,611.00	8,377.56	8,961.41	414.57	415.58	28,006.90	27,182.08
1969	6,633.36	6,804.08	8,268.49	9,556.60	434.65	444.42	29,204.40	28,364.76
1970	6,425.40	6,288.46	8,328,09	9,149.34	445.31	430.98	30,580.90	29,475.35
1971	5,922.49	5,724.88	8,723.62	8,674.24	436.89	414.68	34,475.90	30,581.06
1972	6,070.91	6.026.65	9,064.97	9,423,17	463.04	450.00	32,112.50	31,774.79
1973	6,320.51	6,500.97	11,378.40	10,416.21	516.48	495.62	32,881.70	32,986.08
1974	6,215.15	6,154.63	12,939.10	10,248.39	509.64	492.28	33,477.20	34,113.89
1975	5,338.32	4,938.23	10,130.40	8,849.85	455.01	437.03	35,049.20	35,153.20

*Millions of dollars.

Table A.5. Productivities: Actual and Forecasts, Four Input Factor Case (Inputs by Time Series).

	Actual			Forecasts		
Year	Shipments L+M+EE+C	Production L+M+EE+C	Revenues L+M+EE+C	Shipments L+M+EE+C	Production L+M+EE+C	Revenues L+M+EE+C
1950	3.545	4.752	.784	2.909	3.986	.696
1951	3.411	4.546	.796	3.701	5.200	.838
1952	2.849	3.903	.692	3.297	4.639	.739
1953	3.026	4.214	.701	2.533	3.524	.574
1954	2.639	3.690	.596	2.924	4.120	.633
1955	3.110	4.297	.664	2.652	3.699	.588
1956	2.855	3.952	.621	3.178	4.504	.684
1957	2.620	3.696	.553	2.554	3.596	.550
1958	2.123	3.021	.464	2.429	3.441	.519
1959	2.305	3.105	.485	2.337	3.270	.498
1960	2.256	3.116	.462	2.443	3.436	.514
1961	2.116	3.136	.438	1.934	2.692	.407
1962	2.184	3.044	.447	1.888	2.617	.395
1963	2.283	3.302	.454	2.208	3.100	.454
1964	2.369	3.545	.465	2.505	3.550	.509
1965	2.396	3.399	.471	2.292	3.249	.462
1966	2.238	3.335	.454	2.019	2.855	.404
1967	2.077	3.150	.413	2.211	3.149	.439
1968	2.114	3.025	.415	2.342	3.346	.462
1969	2.108	3.172	.397	2.127	3.035	.417
1970	1.983	2.873	.364	1.963	2.789	.382
1971	1.869	2.587	.353	1.823	2.585	.351
1972	1.924	2.793	.359	1.970	2.807	.378
1973	2.181	2.951	.416	2.110	3.018	.404
1974	2.060	2.742	.418	1.852	2.641	.351
1975	1.569	2.288	.330	1.702	2.419	.319
1976	1.688	2.416	.325	1.736	2.471	.323
1977				1.939	2.778	.362
1978				1.741	2.486	.321
1979				1.381	1.950	.248
1980				1.461	2.072	.262
1981				1.761	2.524	.321
1982				1.636	2.339	.294
1983				1.245	1.757	.215
1984				1.271	1.799	.219
1985				1.620	2.322	.287
1986				1.570	2.250	.276

Table A.6. Productivities: Actual and Forecasts, Three Input Factor Case (Inputs by Time Series).

	Actual			Forecasts		
Year	Shipments / L+M+EE+C	Production / L+M+EE+C	Revenues / L+M+EE+C	Shipments / L+M+EE+C	Production / L+M+EE+C	Revenues / L+M+EE+C
1950	5.287	7.087	1.169	4.538	6.218	1.086
1951	5.177	6.901	1.208	5.986	8.410	1.355
1952	4.711	6.454	1.144	5.502	7.741	1.233
1953	4.980	6.935	1.154	4.532	6.304	1.027
1954	4.862	6.799	1.099	5.162	7.275	1.118
1955	5.430	7.501	1.159	4.989	6.959	1.106
1956	5.134	7.105	1.116	5.957	8.441	1.282
1957	5.080	7.167	1.071	4.882	6.874	1.052
1958	4.858	6.912	1.062	5.128	7.265	1.095
1959	5.162	6.952	1.086	5.539	7.752	1.182
1960	5.281	7.295	1.082	5.781	8.131	1.217
1961	5.294	7.847	1.096	4.736	6.590	.997
1962	5.418	7.550	1.109	4.861	6.736	1.016
1963	5.769	8.342	1.146	5.584	7.841	1.148
1964	5.883	8.801	1.154	6.427	9.107	1.306
1965	5.914	8.390	1.163	5.947	8.431	1.199
1966	5.793	8.632	1.176	5.171	7.310	1.036
1967	5.854	8.877	1.165	5.919	8.430	1.176
1968	5.947	8.511	1.167	6.674	9.533	1.318
1969	6.121	9.211	1.154	6.269	8.941	1.229
1970	5.974	8.653	1.097	5.812	8.260	1.130
1971	5.771	7.985	1.088	5.569	7.899	1.074
1972	5.885	8.542	1.099	6.179	8.801	1.186
1973	6.117	8.279	1.167	6.616	9.462	1.265
1974	5.567	7.411	1.129	5.320	7.588	1.008
1975	5.021	7.325	1.055	4.836	6.874	.906
1976	5.449	7.797	1.049	5.622	8.001	1.047
1977				6.392	9.158	1.194
1978				5.789	8.264	1.068
1979				4.614	6.517	.829
1980				4.877	6.920	.876
1981				5.855	8.392	1.066
1982				5.396	7.717	.971
1983				4.060	5.731	.702
1984				4.089	5.786	.705
1985				5.124	7.346	.909
1986				4.871	6.979	.857

Table A.7. Productivities: Actual and Forecast, Four Input Factor Case (Inputs by Regression).

	Actual			Forecasts		
Year	Shipments / L+M+EE+C	Production / L+M+EE+C	Revenues / L+M+EE+C	Shipments / L+M+EE+C	Production / L+M+EE+C	Revenues / L+M+EE+C
1950	3.545	4.752	.784	2.922	4.003	.699
1951	3.411	4.546	.796	3.322	4.666	.752
1952	2.849	3.903	.692	3.209	4.515	.719
1953	3.026	4.214	.701	2.781	3.869	.630
1954	2.639	3.690	.596	2.981	4.201	.646
1955	3.110	4.297	.664	2.600	3.627	.577
1956	2.855	3.952	.621	2.915	4.130	.627
1957	2.620	3.696	.553	2.625	3.695	.565
1958	2.123	3.021	.464	2.539	3.597	.542
1959	2.305	3.105	.485	2.295	3.211	.490
1960	2.256	3.116	.462	2.331	3.279	.491
1961	2.116	3.136	.438	2.020	2.811	.425
1962	2.184	3.044	.447	1.881	2.606	.393
1963	2.283	3.302	.454	2.079	2.919	.427
1964	2.369	3.545	.465	2.245	3.182	.456
1965	2.396	3.399	.471	2.193	3.109	.442
1966	2.238	3.335	.454	2.059	2.910	.412
1967	2.077	3.150	.413	2.208	3.145	.439
1968	2.114	3.025	.415	2.246	3.208	.443
1969	2.108	3.172	.397	2.148	3.063	.421
1970	1.983	2.873	.364	1.993	2.832	.387
1971	1.869	2.587	.353	1.890	2.681	.364
1972	1.924	2.793	.359	1.963	2.796	.377
1973	2.181	2.951	.416	2.038	2.915	.390
1974	2.060	2.742	.418	1.913	2.728	.362
1975	1.569	2.288	.330	1.784	2.536	.334
1976	1.688	2.416	.325	1.775	2.526	.331
1977				1.933	2.770	.361
1978				1.789	2.554	.330
1979				1.509	2.131	.271
1980				1.565	2.221	.281
1981				1.805	2.587	.329
1982				1.706	2.439	.307
1983				1.374	1.940	.238
1984				1.396	1.975	.241
1985				1.686	2.418	.299
1986				1.644	2.356	.289

Table A.8. Productivities: Actual and Forecasts, Three Input Factor Case (Inputs by Regression).

	Actual			Forecasts		
Year	Shipments / L+M+EE+C	Production / L+M+EE+C	Revenues / L+M+EE+C	Shipments / L+M+EE+C	Production / L+M+EE+C	Revenues / L+M+EE+C
1950	5.287	7.087	1.169	4.484	6.144	1.073
1951	5.177	6.901	1.208	5.061	7.110	1.146
1952	4.711	6.454	1.144	5.122	7.206	1.148
1953	4.980	6.935	1.154	4.872	6.778	1.104
1954	4.862	6.799	1.099	5.206	7.336	1.128
1955	5.430	7.501	1.159	4.979	6.944	1.104
1956	5.134	7.105	1.116	5.396	7.646	1.161
1957	5.080	7.167	1.071	5.250	7.392	1.131
1958	4.858	6.912	1.062	5.267	7.461	1.125
1959	5.162	6.952	1.086	5.150	7.208	1.099
1960	5.281	7.295	1.082	5.291	7.442	1.114
1961	5.294	7.847	1.096	5.068	7.051	1.067
1962	5.418	7.550	1.109	5.008	6.941	1.047
1963	5.769	8.342	1.146	5.323	7.475	1.095
1964	5.883	8.801	1.154	5.571	7.895	1.132
1965	5.914	8.390	1.163	5.604	7.944	1.130
1966	5.793	8.632	1.176	5.556	7.854	1.113
1967	5.854	8.877	1.165	5.766	8.211	1.146
1968	5.947	8.511	1.167	5.866	8.379	1.158
1969	6.121	9.211	1.154	5.851	8.345	1.147
1970	5.974	8.653	1.097	5.782	8.218	1.124
1971	5.771	7.985	1.088	5.754	8.161	1.109
1972	5.885	8.542	1.099	5.884	8.381	1.129
1973	6.117	8.279	1.167	6.008	8.592	1.149
1974	5.567	7.411	1.129	5.961	8.501	1.129
1975	5.021	7.325	1.055	5.906	8.395	1.107
1976	5.449	7.797	1.049	5.956	8.476	1.109
1977				6.141	8.799	1.147
1978				6.078	8.677	1.121
1979				5.860	8.275	1.052
1980				5.985	8.491	1.075
1981				6.241	8.945	1.137
1982				6.212	8.884	1.118
1983				5.957	8.408	1.030
1984				6.034	8.538	1.041
1985				6.336	9.083	1.124
1986				6.349	9.097	1.117

Table A.9. Productivities Capacity Expansion.

Year	Production / L+M+EE+C	Production / L+M+EE
1977	2.590	8.686
1978	2.534	8.758
1979	2.483	8.829
1980	2.435	8.897
1981	2.391	8.964
1982	2.350	9.029
1983	2.312	9.093
Average Annual Rate	-1.93%	+0.76%

Table A.10. Variables Adjusted Data.

	Dependent Variables			Independent Variables			
	Y1	Y2	Y3	X1	X2	X3	X4
Year	Shipments (Thousands of Tons)	Production (Thousands of Tons)	Revenues (Millions of Dollars)	GPDI/GNP (Percent)(1)	Per Capita GNP (Const. 1958 Dollars)	Per Capita Personal Disposable Income (Const. 1958 Dollars)	Industrial Production Index (1957-59=100)
1975	79,957	116,642	16,807.20	11.35	3,758	2,825	188
1974	109,472	145,720	22,202.94	15.43	3,875	2,845	206
1973	111,430	150,799	21,248.99	16.46	3,989	2.945	208
1972	91,805	133,241	17,151.00	15.77	3,795	2,779	190
1971	87,038	120,443	16,414.39	14.89	3,605	2,683	177
1970	90,798	131,514	16,675.33	14.31	3,526	2,610	177
1969	93,877	141,262	17,704.38	15.23	3,580	2,534	183
1968	91,856	131,462	18,024.20	14.94	3,518	2,474	166
1967	83,897	127,213	16,693.90	14.94	3,388	2,399	158
1966	89,995	134,101	18,271.49	16.61	3,342	2,331	156
1965	92,666	131,462	18,230.56	16.06	3,180	2,239	143
1964	84,945	127,076	16,661.28	14.94	3,006	2,116	132
1963	75,555	109,261	15,008.00	14.96	2,904	2,009	124
1962	70,552	98,328	14,445.20	14.98	2,839	1,969	118
1961	66,126	98,014	13,690.21	13.87	2,706	1,909	110
1960	71,149	98,282	14,581.33	14.85	2,699	1,883	109
1959	69,377	93,446	14,599.69	15.81	2,700	1,882	106
1958	59,914	85,255	13,097.05	13.62	2,558	1,823	94
1957	79,895	112,715	16,850.54	15.80	2,656	1,814	101
1956	83,251	115,216	18,091.29	17.41	2,674	1,810	100
1955	84,717	117,036	18,083.16	17.21	2,650	1,795	97
1954	63,153	88,312	14,272.22	14.86	2,483	1,713	86
1953	80,152	111,610	18,569.22	14.67	2,576	1,727	91
1952	68,004	93,168	16,519.22	15.13	2,507	1,679	84
1951	78,929	105,200	18,409.38	18.13	2,460	1,659	81
1950	72,232	96,836	15,968.86	19.50	2,342	1,646	75

Table A.10 (Cont'd). Variables Adjusted Data.

	Independent Variables							
	X5	X6	X7	X8	X9	X10	X11	X12
	New Housing Started (2)	Motor Vehicle Production(3)	Steel Imports Shipments	Plant and Equipment Expenditures 1967 Dollars)	Personal Consumption in Durable Goods (Const. 1958 Dollars)	Personal Consumption Expenditures (Const. 1958 Dollars)	Per Capita Personal Expenditures (Const. 1958 Dollars)	Industrial Index Durables Manufactures 1957-59=100
				.67	105.6	554.1	2,582	176
				.08	103.1	539.5	2,546	206
				.54	113.6	552.1	2,624	207
				.01	104.9	527.3	2,525	184
				.29	92.5	496.4	2,398	168
				.46	83.8	477.5	2,331	172
				.28	85.6	469.1	2,315	187
				.10	80.7	452.6	2,250	170
				.47	72.8	430.3	2,161	164
				.47	71.7	418.1	2,123	165
				.45	66.6	397.7	2,047	148
				.16	58.5	372.1	1,937	134
				.41	53.2	352.4	1,860	125
				.36	49.2	338.6	1,814	118
				.26	43.9	322.6	1,756	107
				.56	44.9	316.1	1,749	109
				.14	44.1	307.7	1,738	106
				.62	37.9	290.1	1,670	90
				.61	41.1	287.4	1,678	104
				.63	41.0	280.4	1,667	104
1955	1,646	9,169	1,467	33.98	43.2	274.2	1,646	102
1954	1,551	6,601	1,254	31.56	35.0	253.0	1,559	88
1953	1,438	7,323	2,483	33.40	31.5	248.9	1,560	100
1952	1,504	5,539	1,697	31.50	28.2	238.6	1,520	89
1951	1,491	6,765	3,519	29.78	28.6	231.5	1,500	83
1950	1,952	8,003	2,030	25.91	32.1	230.5	1,520	74

(1) Percent of GPDI in respect to GNP (GPDI = Gross Private Domestic Investment).
(2) 1950-1958 includes only non-farm series.
(3) Production of automobiles, trucks, and buses.

Table A.11. Multiple Regression Results.

Stepwise Regression	Dependent Variable: Shipments (Tons)						Dependent Variable: Production (Tons)						Dependent Variables: Revenues ($)					
	Independent Variables						Independent Variables						Independent Variables					
	X1 to X8			X1 to X12			X1 to X8			X1 to X12			X1 to X8			X1 to X12		
Step Number	Var	R^2	MSE $x10^6$	Var	R^2	MSE $x10^6$	Var	R^2	MSE $x10^6$	Var	R^2	MSE $x10^6$	Var	R^2	MSE $x10^6$	Var	R^2	MSE $x10^6$
1	X6	69.99	51.4	X6	69.99	51.4	X8	74.86	90.0	X12	77.80	79.5	X6	35.31	3.06	X6	35.31	3.06
2	X8	74.83	45.0	X12	76.29	42.4	X1	83.67	61.0	X10	87.87	45.3	X1	42.75	2.83	X1	42.75	2.83
3	X1	82.26	33.1	X1	86.86	24.5	X5	86.06	54.5	X1	91.2	34.2	X2	55.21	2.31	X12	57.65	2.19
4	X5	84.91	29.5	X10	88.94	21.7	X6	89.68	42.3	X6	92.01	32.7	X5	63.38	1.98	X10	63.84	1.96
5	X2	87.34	26.0	X3	90.56	19.4	X7	90.73	39.8	X7	92.57	31.9	X4	68.59	1.78	X9	72.51	1.56
6	X7	88.21	25.5	X5	92.20	16.8	X2	90.85	41.4	X8	93.42	29.8*	X8	72.21	1.66	X5	78.32	1.29
7	(X8)[2] REM	88.21	24.2	X8	93.41	15.0*[1]	X3	92.54	35.6*	X5	93.70	30.1	(X6) REM	72.20	1.58*	(X6) REM	78.32	1.23
8	X3	88.97	23.8*	X7	93.66	15.3	X4	92.67	37.0	X3	94.04	30.1	X7	73.59	1.58	X3	81.59	1.10
9	X4	88.98	25.1	X9	93.72	16.1				X2	94.09	31.7	X3	74.64	1.60	X8	86.24	0.87
10				X2	93.89	16.7				X9	94.23	33.0	X6	74.79	1.68	X2	89.24	0.72
11																X6	91.23	0.62*
12																X7	91.45	0.64

[1]*Refers to minimum mean square error model.
[2]Parenthesis indicate variable removed at step.

APPENDIX II

This experiment was carried on in order to provide with an alternative approach for obtaining forecasts of the output factors. It was the purpose of the experiment, to obtain, through analysis of historical data, relationships between yearly level of outputs and the yearly value of several demand indicators.

It is known that approximately 60 percent of steel demand[59] comes from the following market sectors

1. Automotive
2. Industrial and residential construction
3. Containers, packaging and shipping materials
4. Machinery, industrial equipment and tools
5. Appliances and other commercial equipment
6. Railroads
7. Electrical equipment

Indicators related to the above areas of demand are selected and used in an attempt to capture the behavior of the more important steel market sectors.

Some of the indicators require adjustments to constant value terms. Others are expressed in ratios, percentages, and physical units and do not require adjustments.

The method used to analyze this data is through multiple regression analysis. The series of yearly output factor levels in tons and in constant dollar for revenues, is used as the dependent variable and the series of the various indicators in constant value terms are used as the independent variables.

The results of the experiment will permit the selection of a subset of the indicators that provide with adequate explanation of the variations in the outputs series.

The series are analyzed from 1950 to 1975. The following is a list of the indicators used as independent variables.

X1: Gross Private Domestic Investment as percent of Gross National Product, GNP

X2: Per Capita GNP

X3: Per capita personal disposable income

X4: Industrial production index (manufacturers)

X5: New housing started

X6: Motor vehicle production

X7: Steel imports shipments

X8: Business expenditures for new plant and equipment

In addition, four other indicators were used. These are related to some of the ones presented above.

X9: Personal consumption on durable goods

X10: Personal consumption expenditures

X11: Per capita personal expenditures

X12: Industrial production index, durable manufacturers.

The series of the indicators are obtained from the U. S.

Statistical Abstract.[63] The adjusted data that was used in the experiment is shown in Table A.10.

Two sets of results are presented, one by using variables X1 to X8 and another by using all twelve independent variables. This distribution is done because some of the indicators considered and specially X9 through X12 might be correlated with indicators X1 through X8. This can cause problems of multicolinearity in the regression analysis.

Results

Table A.11 shows the stepwise regression results for the three outputs. This procedure uses partial correlation coefficients to bring variables into the model and can also remove variables that were in the equation at earlier steps but that there are no longer significant at later steps. Not all of the eight or twelve independent variables are included in the models because the procedure requires a level of significance for the variables to be in the equation.

Analysis of the results can be summarized in the following points:

Twelve Variable Case

1. For each of the three output factors, even though the order of entering the variables vary, the first four variables included in the model are X1, X6, X10 and X12. This is a convenient result because the three output factors can be related to the same four demand indicators.
2. In the twelve variable case, R^2 values for the models that

include only the first four entered variables are 88.94, 92.01 and 63.84 percent for shipments, production, and revenues respectively. However, better predictive model can be obtained by including several other variables until the model shows the minimum mean square error, (MSE).

3. The lower R^2 values for revenues shows that the variation in shipments and production levels are better explained by these demand indicators than the variation in revenues.

Eight Variable Case

1. Variables X1, X5, and X6 are included in the first four steps. Variable X8 is included in the first two steps in the case of shipments and production.
2. R^2 values for the same number of variables included in the model are close to the values obtained for the twelve variable case. This means that even through X10 and X12 are highly significant, large variation can be explained without having these variables in the model.
3. As with the twelve variable case the minimum mean square error is obtained by including two or three more variables, and the R^2 values for revenues are lower than for shipments and production.

After having obtained empirical relationships that would link the output factors to demand indicators, forecasts of the demand indicators can be used to predict the level of the output factors. The problem with this approach is that, if its difficult to adequately model the indicator's series, the forecasts will be in error and this in turn can cause substantial errors in the output predictions.

Our experiment attempted to obtain adequate time series models for variables X1, X6, X10 and X12 and use these to predict outputs. The results obtained with this approach were not satisfactory. It was difficult to obtain adequate forecasts for the indicators by time series, because their variations can be caused by many factors, other than time. The predictions of outputs from these forecasts failed to show the typical steel industry cyclical behavior.

Another source of complication in relation with the regression experiment is the presence of multicolinearity among the independent variables. This is caused because there is fairly large correlation among the indicators.

Multicolinearity was checked by observing the large single correlation coefficients among the independent variables and by computing the inverse of the correlation matrix in order to extract the variance inflation factor (VIF). VIF's larger than 10 is a sign that multicolinearity is present, meaning that the independent variables are correlated giving unstable parameter estimates.

Most of the VIF's computed were larger than 30, the smaller being 4.1, 4.0, and 18.2 for X1, X5, and X5 respectively.

Despite these statistical complications, the experiment has given insight about the more significant demand indicators that can be used to predict the level of outputs in the steel industry. This method of prediction can be useful if reliable forecasts or expectations about future steel demands from its major market sectors can be obtained.

REFERENCES

1. Herbert Stein, "The Meaning of Productivity," The Meaning and Measurement of Productivity, Bulletin 1714, U. S. Dept. of Labor Statistics (Washington, D. C.), p. 5. (Hereafter cited as "Stein".)

2. Productivity Indexes for Selected Industries, Various editions, U. S. Department of Labor, Bureau of Labor Statistics, U. S. Government Printing Office. (Hereafter cited as "B.L.S. Productivity Indexes.")

3. William T. Hogan S. J., The 1970s: Critical Years for Steel, (Lexington, Mass.: Lexington Books, 1972), p. 79. (Hereafter cited as "Hogan, 1972.")

4. Hogan, 1972, p. 81.

5. Solomon Fabricant, "Basic Facts on Productivity Change: An Introduction by Solomon Fabricant," Productivity Trends in the United States by John W. Kendrick, (Princeton, N. J., 1961), p. xxxv.

6. C. E. Craig and R. C. Harris, "Productivity Concepts and Measurements: A Management Viewpoint," unpublished Master's thesis, Massachusetts Institute of Technology, 1972, p. 41. (Hereafter cited as "Craig and Harris.")

7. Stein, p. 1.

8. Craig and Harris, pp. 28-29.

9. Craig and Harris, p. 27.

10. Craig and Harris, p. 29.

11. John W. Kendrick, Productivity Trends in the United States, (Princeton, N. J., 1961), pp. 85-99. (Hereafter cited as "Kendrick, 1961.)

12. "The Disaster in Productivity," Fortune, December 1974, p. 24.

13. Kendrick, p. 85.

14. John W. Kendrick and D. Creamer, Measuring Company Productivity, The Conference Board, 1965, pp. 6-8. (Hereafter cited as "Kendrick and Creamer.")

15. W. E. G. Salter, Productivity and Technological Change, (London, 1960), p. 4.

16. William W. Hines, "Productivity, Productivity Measurement and Industrial Engineering Functions," Georgia Institute of Technology, 1976, p. 1.

17. Kendrick and Creamer, pp. 6-8.

18. Kendrick, 1961.

19. B.S.L. Productivity Indexes.

20. William W. Hines, "Guidelines for Implementing Productivity Measurement," Industrial Engineering, June 1976, p. 40.

21. Kendrick and Creamer, pp. 59-101.

22. Kendrick and Creamer, p. 59.

23. Craig and Harris, p. 43.

24. Craig and Harris, p. 52.

25. B. W. Taylor, III and K. R. Davis, "Corporate Productivity, Getting It All Together," Industrial Engineering, March 1977, p. 32. (Hereafter cited as "Taylor and Davis.")

26. Jerome A. Mark, "Measuring Industry Productivity," Improving Productivity Through Company Measurement, Series 2, National Center for Productivity and Quality of Working Life, (Washington, D. C., 1976), p. 32.

27. Jerome A. Mark, "Concepts and Measures of Productivity," The Meaning and Measurement of Productivity, Bulletin 1714, U. S. Dept. of Labor Statistics, p. 10. (Hereafter cited as "Mark, B.L.S. Bulletin, 1714.")

28. Kendrick and Creamer, p. 14.

29. Kendrick, 1961, p. 612.

30. Kendrick and Creamer, p. 29.

31. Kendrick and Creamer, p. 23.

32. Kendrick and Creamer, p. 24.

33. Mark, B.L.S., Bulletin 1714, p. 11.

34. Kendrick and Creamer, p. 33.

35. Kendrick and Creamer, p. 41.

36. Kendrick and Creamer, pp. 41-42.

37. Mark, B.L.S., Bulletin 1714, p. 9.

38. B.L.S. Productivity Indexes, 1977 Edition.

39. William T. Hogan S. J., Productivity in the Steel Industry: 1920-1946, (New York, 1950).

40. William T. Hogan S. J., Economic History of the Iron and Steel Industry of the United States, Volumes 4 and 5, (Lexington, Mass., 1971). (Hereafter cited as "Hogan, 1971.")

41. Hogan, 1971, p. 2090.

42. Hogan, 1972, pp. 88-91.

43. Hogan, 1972, p. 92.

44. Ralph F. Thompson, U. S. Industrial Outlook 1977, (Washington, D. C., 1977), p. 71. (Hereafter cited as "Thompson, U. S. Industrial Outlook 77.")

45. Hogan, 1972, pp. 95-111.

46. "The United States Steel Industry and Its International Rivals," Bureau of Economics, (Washington, D. C., 1977).

47. J. Varga, Jr. and H. W. Lownie, Jr., "A Systems Analysis Study of the Integrated Iron and Steel Industry," (Battelle Memorial Institute, 1969).

48. Roy Taub, "Output Rising, But Well Below Capacity," Standard and Poors Industry Outlooks, 1976. (Hereafter cited as "Taub, Standard and Poors.")

49. C. S. Russell and W. J. Vaughan, Steel Production: Processes, Products and Residuals, (Baltimore, Md., 1976).

50. Julian Szekely, Steel Industry and the Energy Crisis, (New York, 1975).

51. J. Grieve Smith and T. P. Miles, "Total Productivity of the British Iron and Steel Industry," 1950-1960, Productivity in the Iron and Steel Industry, (London, 1962), pp. 18-26.

52. H. W. Waring and T. Dennison, "The Study of Productivity in the Iron and Steel Industry," Productivity in the Iron and Steel Industry, (London, 1962), pp. 1-5.

53. P. Wykeman, "Old and New Ways of Assessing Productivity," Productivity in the Iron and Steel Industry, (London, 1962), pp. 12-17.

54. E. W. Voice and K. G. Dixon, "Iron-making Productivity," Productivity in the Iron and Steel Industry, (London, 1962), pp. 6-11.

55. David R. Dilley, "Financing Future Capital Investments," The Future of the World's Steel Industry, (New York, 1976), p. 129.

56. Thompson, U. S. Industrial Outlook 77, p. 73.

57. Taub, Standard and Poors, p. S52.

58. R. K. Sharkey, U. S. Industrial Outlook 1978, (Washington, D. C., 1978). (Hereafter cited as "Sharkey, U. S. Industrial Outlook 78.")

59. American Iron and Steel Institute, Annual Statistical Reports, (Washington, D. C., Various years).

60. D. C. Montgomery and L. A. Johnson, Forecasting and Time Series Analysis, 1976.

61. N. R. Draper and H. Smith, Applied Regression Analysis, (New York, 1966).

62. SPSS, Statistical Package for the Social Sciences, Second Edition, (McGraw-Hill Book Co., 1975).

63. U. S. Dept. of Commerce, Statistical Abstract of the United States, (Washington, D. C., Various years).

SELECTED BIBLIOGRAPHY

American Iron and Steel Institute, Annual Statistical Reports: American Iron and Steel Institute. Washington, D. C.

Craig, C. C. and R. C. Harris, "Productivity Concepts and Measurements: A Management Viewpoint," unpublished Master's thesis, Massachusetts Institute of Technology, 1972.

Dilley, David R., "Financing Future Capital Expenditures," The Future of the World's Steel Industry, Marcel Dekker, Inc., New York, 1976.

Draper, N. R. and H. Smith, Applied Regression Analysis, John Wiley and Sons, New York, 1966.

Fabricant, Solomon, "Basic Facts on Productivity Change, An Introduction by Solomon Fabricant," Productivity Trends in the United States by John W. Kendrick, Princeton University Press, Princeton, N. J., 1961.

Fortune, "The Disaster in Productivity," December 1974.

Hines, WIlliam W., "Guidelines for Implementing Productivity Measurement," Industrial Engineering, June 1976.

Hogan, William T., Productivity in the Steel Industry 1920-1946, Forkham University Press, New York, 1950.

Hogan, William T., Economic History of the Iron and Steel Industry in the United States, Volumes 4 and 5, Lexington Books, Lexington, Mass., 1971.

Hogan, William T., The 1970's: Critical Years for Steel, Lexington Books, Lexington, Mass., 1972.

Kendrick, John W., Productivity Trends in the United States, Princeton University Press, Princeton, N. J., 1961.

Kendrick, John W. and D. Creamer, Measuring Company Productivity, The Conference Board, Studies in Business Economics, Number Eighty Nine, New York, 1965.

Mark, Jerome A., "Concepts and Measures of Productivity," Meaning and Measurement of Productivity, Bulletin 1714, U. S. Department of Labor Statistics, 1971.

Krol, Joseph, "The Use of Capital-Labor Ratio in Design of Large Scale Systems," Georgia Institute of Technology.

Mark, Jerome A., "Measuring Company Productivity," Improving Productivity Through Industry and Company Measurement, National Center for Productivity and Quality of Working Life, Washington, D. C., 1976.

Montgomery, D. C. and L. A. Johnson, Forecasting and Time Series Analysis, McGraw-Hill, Inc., 1976.

Mundel, Marvin E., "Measures of Productivity," Industrial Engineering, May 1976.

"Prices and Costs in the United States Steel Industry," Report to the President by the Council on Wage and Price Stability U. S. Government Printing Office, October 1977.

Productivity in the Iron and Steel Industry, Special Report 75, The Iron and Steel Institute, London, 1962.

Russell,Clifford S. and William J. Vaughan, Steel Production: Processes, Products, and Residuals. Resources for the Future, John Hopkins University Press, Baltimore, Md., 1976.

Salter, W. E. G., Productivity and Technical Change, Cambridge University Press, Cambridge, 1966.

Stein, Herbert, "The Meaning of Productivity," The Meaning and Measurement of Productivity, Bulletin 1714, U. S. Department of Labor Statistics, 1971.

Taub, Roy, "Output Rising, But Well Below Capacity," Standard and Poors, Industry Outlooks, 1976.

The Future of the World's Steel Industry, ed. by Julian Szekely, Marcel Dekker, Inc., New York, 1976.

U. S. Bureau of Labor Statistics (B.L.S.), Productivity Indexes for Selected Industries, U. S. Government Printing Office, Washington, D. C., (various years).

U. S. Department of Commerce, U. S. Industrial Outlooks, U.S. Government Printing Office, Washington, D. C., (various years).

U. S. Department of Commerce, Statistical Abstract of the United States, Government Printing Office, Washington, D. C., (various years).

The Steel Industry and the Energy Crisis, ed. by Julian Szekely, Marcel Dekker, Inc., New York, 1975.

"The United States Steel Industry and Its International Rivals," Federal Trade Commission, Bureau of Economics, U. S. Government Printing Office, Washington, D. C., November 1977.

Varga, J., Jr. and H. W. Lownie, Jr., "A Systems Analysis Study of the Integrated Iron and Steel Industry," Report by Battelle Memorial Institute, National Technical Information Service, Springfield, Va., 1969.